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for Western Union's Supervisory, Maintenance and Engineering Personnel.

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JANUARY 1961

**Engineering of Microwave Systems
Appendix**

London Equipment and Repair Shops

**Technical Associates of Western Union — IV
Technical Operations, Incorporated (Tech/Ops)**

Dispatching

**Mitigation of Power Disturbance on
a Loaded Submarine Cable**

Neutralization of Static Electricity — III

Telecommunications Literature

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**VOLUME 15
NUMBER 1**

Government Relations

K. W. HEBERTON

Vice President
Government Relations



Government policy, or the lack of it, plays an important part in the development of technical as well as other phases of your company's operations. I believe the Congress and the executive departments and agencies are fully aware of the technological accomplishments that make Western Union the leader in the field of record communications. The progress of Western Union has been considerably enhanced by the challenging problems of modern telecommunications.

It is essential therefore that our program for progress be implemented at every opportunity to encourage the development of our services to satisfy the ever increasing and vastly complex requirements of the national and public interest for new and diversified telecommunications media.

An important tool in this process of education is the Technical Review. To all who assist in this excellent endeavor, I congratulate you for a continuing job well done.

A handwritten signature in cursive script that reads "K.W. Heberton".

January 1, 1961



ENGINEERING MICROWAVE SYSTEMS

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The main body of this paper, which was published in the Technical Review in July 1960, dealt primarily with the broad aspects of microwave relaying for communication. At the time of preparation it was considered desirable to amplify and support some of the statements so that more complete data would be available to those interested in further details on the subject. This appendix was prepared for that purpose.

Engineering of Microwave Systems Appendix

Relationship between System Performance, Capacity and Length — Interference — Remote Monitor and Control Facilities — Site Selection — Reflection in Antenna Feed Lines — Reliability — Calculation of Reliability — Requirements for Multiplex Terminal Equipment and Derived Voice-Frequency Bands — Example of Economics Relating to a Microwave Trunk System.

RELATIONSHIP BETWEEN SYSTEM PERFORMANCE, CAPACITY AND LENGTH

THE CCITT has adopted a hypothetical circuit as a reference which permits the establishment of standards of performance and circuit quality. This circuit is 1550 miles (2500 km) in length and is divided into three trunk sections. At the end of each trunk, the sections are connected together at audio frequency. For radio systems of more than 60 telephone channels, the CCIR further divides this system so that each trunk is composed of three subsections for a total of nine sets of radio modulators and demodulators. At the end of the intermediate subsections, demodulation of frequency-division multiplex signals to group or supergroup levels is assumed.

The CCITT has specified as a standard for the performance of this reference circuit that the mean psophometric (weighted) noise power in a voice-frequency channel during any hour should not exceed 10,000 picowatts (1 picowatt is 10^{-12} watt) measured at a point of zero dbm reference signal (a zero test level point). The CCIR has further specified that the radio system should contribute not more than 7500 picowatts mean value in any hour and not more than 5000 picowatts mean value in the busy hour in the absence of fading. Table I shows a typical distribution of the total noise in one subsection of 172 miles composed of two terminals and five repeater stations having

an average spacing of 28.7 miles (46.2 km). This includes white noise without fading, intermodulation noise due to modulators and demodulators at terminals, variations in the response of filters, mismatch of transmission lines and interference. It also shows total noise with a 5-db increase in mean white noise because of fading. To insure that the distortions of the individual sections add on a power relationship, it may be necessary to introduce "frequency-frogging," i.e., interchange of the position of groups and/or supergroups at periodic intervals along the system.

capable of providing 600 or more voice-frequency bands of sufficiently high quality to meet the CCITT-CCIR standard which is equivalent to 50 db test-tone-to-noise (psophometric) ratio. If such a system were extended to 4000 miles (6450 km), as for transcontinental service in the USA, it should yield a signal-to-noise ratio of 46 db (noise level 25,000 picowatts) which is essentially the same as the objective for most systems in North America. Extended further to provide 8500 miles (14,000 km) service, a signal-to-noise ratio of slightly better than 42 db

TABLE I

White Noise (21.5 pW per hop)	129 pW (no fading)
Intermodulation Noise (I.M.)	
(a) Terminals	126 pW
(b) Transmission Lines	150 pW
(c) Filters	100 pW
(d) Interference	50 pW
Total I.M.	426 pW
Total Noise	555 pW (no fading)
With 5 db Effective Fade add	278 pW
Total Radio Noise	833 pW (any hour)
Multiplex Equipment Noise	278 pW
Total Noise	1111 pW (any hour)

Such a system offers a reasonable approximation to the basic requirements for the proposed LATIN (R.I.T.A.L.) routes. The principal difference lies in the more frequent introduction of terminals along this system; i.e., an average of about 11 terminal-to-terminal stations occur in 1550 miles (2500 km) as compared with nine for the reference circuit. This does not change the performance greatly, and routing of the radio system may result in the use of spurs or tributaries which feed two or more cities lying off the main route; hence, this factor may be ignored in preliminary planning.

Equipments are available which are

(55,000 picowatts) would be expected. Of course, this applies only to through channels which traverse the entire route. Any 1550-mile circuit on the system would conform to the CCITT standard of 50 db.

Although 42 db may not be truly high quality, it certainly is a reasonably acceptable one. It should be noted that this is the mean value during the busy hour (when intermodulation noise is the highest) at a time that the system is degraded by fading. Most of the time the circuit quality should be several db better. Furthermore, a significant improvement in performance could be obtained, even during the fading and busy hour conditions,

If the radio equipment were operated with fewer voice channels than the rated capacity. For example, depending on the exact system capacities, a system which was rated for 600 bands but operated with only 200 could provide 3 to 5 db better signal-to-noise ratios (one-half to one-third the noise powers). This would result in qualities for the longest circuits envisioned here essentially equal to the North Amer-

ican objectives for transcontinental voice circuits.

Companders are one of the methods of reducing the effect of noise on channels used for voice and this method has found widespread use today. They are quite effective in that an apparent circuit improvement of as much as 20 db may be realized, but they are not usable on telegraph or data channels.

INTERFERENCE

The primary sources of interference in a high-capacity microwave relay system tend to be of local origin. A complete system designed to provide several two-way radio circuits will usually have a number of combinations of transmitter and receiver frequencies which can result in degradation of transmission quality as explained below.

One serious source of interference can be the operation of a transmitter on the image frequency of a receiver, i.e., on a frequency separated from the local oscillator by the intermediate frequency of the receiver but on the opposite side of the local oscillator from the desired frequency. Although filtering can be provided to satisfy most practical cases, leakage coupling between adjacent equipments offers serious problems. In general, operation of such a transmitter and receiver at the same location is avoided, if practical.

Similar to the above is the use of a receiver having as its image frequency the received signal of another channel. This condition is much easier to handle than is that of the transmitter mentioned above because the desired and unwanted signals are at approximately the same level, whereas, when a transmitter is involved there may be a difference in level of 70 db or more.

Signals, especially local transmitters, falling on the local oscillator of a receiver must be considered as possible sources of trouble. This includes those on the alternate local oscillator frequency as well. The allowable signal levels for acceptable effects are reasonably high, but the rela-

tively small frequency separation makes this a source of interference which cannot be neglected.

Local oscillators can also cause trouble, particularly if they fall in the passband of other receivers. This is most likely to be a problem if several receivers are multiplexed onto a common antenna. Many transmitters generate their output frequency by mixing an i-f signal with a local oscillator, and their design must be such as to prevent the appreciable spurious energy generated from getting into a receiver at a frequency which can cause interference.

Other signals can cause system degradation without specific frequency relationships. For example, excessive interfering signal levels fed into the limiter of a receiver can raise the threshold level and result in a loss of fade margin. High-level signals in the receiver mixer can also cause problems by generating frequencies which fall in the i-f band.

The above discussion has been in terms of superheterodyne-type equipment which provides amplification at an intermediate frequency, but related problems occur in other systems such as traveling-wave-tube repeaters employing a simple frequency shift between received and transmitted frequency.

A major source of interference is other microwave systems operating in the same frequency band in the same area. The difficulty of coordinating new systems with those already operating grows to major proportions as communication networks expand. Parallel and crossing routes, spurs, junction points, and common ter-

terminal cities all offer special situations. In some cases hundreds of calculations may be required to check all possible interference combinations. There may be, for example, many sources of interference, including "overshoot" signals from relay stations several hops away that are using the same frequencies. While no one combination may be serious, the composite may prevent satisfactory operation.

Among other factors to be considered, radar systems rank high as trouble spots since they use high transmitter power which is generally pulse-modulated, and hence can result in spurious outputs of a magnitude sufficient to interfere with low-power communication systems. Furthermore, local transmitters may radiate harmonics which can cause harmful interference to local receivers operating in the fundamental frequency range if adequate decoupling is not provided.

Several methods may be used to reduce interference into a receiver. Filters are the most obvious. However, the required filtering is usually determined by other factors, such as its effect on transmission. Decoupling between antennas by directivity, whether at the same or different locations, is another possibility of interference reduction. To this, antenna polarization selectivity can be added in some situations, and screens or shields may be used for special cases. Further isolation due to receiver or transmitter mixer bal-

ance and unidirectional transmission lines (circulators and isolators) also helps minimize the filtering required in certain of the interference combinations discussed above.

While a large amount of the design work can be done by calculation, the final results must usually be measured to insure that adequate decoupling has been achieved. Direct measurement of source levels, isolation factors, and/or resultant interfering signals is a second step. Conventional techniques are applicable to such measurements, but these checks are not always sufficient, and tests must be made of the effect that the interfering signals have on traffic channels. These may be made on actual voice-frequency bands, or the results may be deduced from noise power radio measurements in slots introduced in wideband noise signals used to simulate traffic loads on the radio system. Other tests may include spectral distribution measurements of noise throughout the modulation frequency range (baseband) of the radio system as insurance against spikes of noise which can degrade selected bands. Interpretation of these results may be subject to engineering judgment and/or further tests due to the changing effects of interference with variation of modulation levels on both the interfering signal and the circuit under test.

REMOTE MONITOR AND CONTROL FACILITIES

Remote monitor and control facilities, as employed by Western Union, operate over the microwave system below 60 kc. Equipment to monitor and/or control remotely-located apparatus is available in a number of different forms and is based on a number of different approaches. Most of them can be categorized according to certain fundamental characteristics as follows:

1. Degree of monitoring
2. Type of modulation
3. Identification of condition
4. Identification of station reporting
5. Mode of reporting

These will be discussed in some detail and some of the interrelationships pointed out.

1. Degree of Monitoring

Systems may be classified as telemetry and out-of-limit reporting systems. The former reports complete detail of the characteristics monitored and as much information is available to the supervisory station as there would be to a man at the remote station. The out-of-limit systems are much simpler but merely report that a specified characteristic has or has not exceeded some preset limit. Since the basic

requirement for monitoring systems for microwave circuits usually covers only the establishment of which station requires the attention of the maintenance force or what switching operation must be effected, the latter type of system is generally sufficient and is much more economical.

2. Type of Modulation

Information may be sent from the remote station by any of the usual modulation methods such as amplitude modulation, frequency or phase modulation, or the various pulse-modulation methods applied to a signalling tone. For telemetering, frequency modulation is most generally employed. Out-of-limit reporting systems can conveniently use any of the above modulation methods but frequency-shift and pulse-code systems have advantages where satisfactory operation is required in the presence of high noise and/or level variations.

3. Identification of Condition

This characteristic is generally dependent upon the degree of monitoring and related to the method of identification of the station reporting. Telemetry systems generally employ separate tone frequencies for each condition monitored, although several functions can be multiplexed onto one tone by time division, or any one of several functions may be reported when selected by remote control from the supervisory station. For out-of-limit reporting systems, a combination of tone frequencies can be used with coded modulation of each, but the most common form of such systems is based on the use of a pulse train operated with a different condition or bit of information assigned to each pulse, i.e., a time-division system transmitting binary information. As in conventional teleprinter operation, a scanning circuit, commonly electronic, sweeps through the list of conditions and generates a "yes" or "no" for each position in the pulse train. Synchronizing information is supplied to keep a scanner at the

receiving end in step with the transmitter so that the pulse train may be properly decoded.

It should be recognized that the pulse train can be transmitted by any of the tone-modulation methods discussed above.

4. Identification of Station Reporting

If a separate tone frequency is assigned to each specific condition, as in continuous telemetry, the identification of condition also includes the station reporting information.

For systems using one or more coded tones which are common to all stations in a group, the coding will generally include the station identification information as well. It should be mentioned that this method of operation requires sequential reporting by remote stations and some type of either lockout or interrogation scheme to prevent more than one station from reporting at the same time.

A more straightforward method uses frequency-division multiplex to permit several stations to make simultaneous use of a common reporting circuit. A separate tone is assigned to each station and selective filters separate the reports at the receiving end. All stations can report simultaneously and independently, even on a one-way circuit if desired.

5. Mode of Reporting

Most telemetry systems report continuously and operate independently of the receiving end. The supervisory station may or may not have a continuous monitor to display the information being reported.

Other systems report automatically whenever an abnormal condition occurs and continue to report until the condition is corrected or until ordered by remote control to discontinue reporting. Some of these can send an alarm signal to attract the supervisor's attention each time a change of status occurs in any of the conditions monitored; others provide continuous monitoring.

The third method involves interrogation of the remote stations either whenever

trouble is suspected, whenever an "alert" signal is received from the remote station, or continuously in sequence.

The usual aim of all these systems is to determine as quickly as possible which station has an abnormal condition and then to indicate what the trouble is. The continuous automatic interrogation scheme offers a very straightforward approach to accomplish this and can readily be designed to alarm most failures of the reporting system. In general, however, it tends to be more complicated than other systems. Other systems can usually provide characteristics which are as satisfactory from an operating viewpoint and avoid the need that is imposed by interrogation-type systems. This latter requirement can be an important limitation in some applications where the information is to be transmitted by the equipment which is being monitored.

The above characteristics must be integrated into a self-consistent system. An example of a complete equipment suitable for radio relay use may help to clarify the picture. An out-of-limit system is usually sufficient to provide the information necessary for the proper dispatch of maintenance personnel. The equipment might employ a separate tone frequency for each remote station and might frequency-shift modulate each of these tones with a pulse train. The occurrence or absence of each pulse, except the synchronizing pulses and any parity-checking pulses which may be added for error detection, represents the indication of "good" or "bad" for one pre-assigned condition. The remote stations might operate on the basis of no report until a condition changed. The report might then continue until an order to cease transmission was received from the supervisory station. Information might be sent to supervisory personnel at each end of the system to obtain maximum reporting reliability, with only one station being assigned responsibility for monitoring. The system would be designed to be as fail-safe as possible with means for local and remote checking of the reporting equipment possible at any time. The control station would have a station identifi-

cation display which would show which stations were sending alarms, and a common decoder which can be used to analyze the reports from any station selected by the supervisory personnel. After having determined the details of the trouble, the supervisor could order the remote stations to discontinue reporting until new information was available. At any time, however, the supervisor could request a report from the remote stations as a check on his records and on the continuing satisfactory operation of the remote reporting equipment.

The above discussion has been directed toward reporting systems which light an indicator light at a supervisory point in response to closure of a pair of contacts at a remote station. This same system may simply be turned around and caused to close a pair of contacts at the remote station in response to closure of a corresponding pair at the supervisory station, thereby providing remote control facilities. In some equipments these are basically two separate systems; in others, they are integrated. It is generally desirable that the operation of the remote controls be monitored by a reporting system. Furthermore, it may be desirable to have the remote station confirm the order transmitted before a signal is sent to cause that order to be executed. Other features may also be added to insure against improper operation of remote controls.

The arrangement of display units at the remote and supervisory points is quite important to satisfactory operation of the facilities. A considerable amount of "human engineering" of the alarms and controls is desirable to aid the supervisory personnel, especially if they are not associated with the system on a reasonably full-time basis. For exceptionally complex systems, the use of pictorial layouts with indicator lights and switches arranged readily to show conditions in schematic form may be necessary.

Voice communication facilities on a party-line basis are normally provided between the supervisory and remote stations. Interconnection of this circuit and

equipments for mobile radio communication with maintenance personnel enroute between stations may be an important adjunct if, otherwise, the maintainer would be out of contact for extended periods. This can be on an alert-signal basis which informs the man to report to the supervisory station as soon as possible, a coded signal system which tells him to proceed to a specific station at once, or a two-way voice circuit so that the supervisory personnel have confirmation that the instructions have been received and understood.

Auxiliary equipment for monitoring the operation of the traffic channels is a useful adjunct which serves to alert supervisory personnel of degradation in system performance. The important characteristic of such devices is that they must show the troubles that affect the customer. These

can take various forms such as a monitor speaker on an idle channel, or a detector on a pilot tone which is transmitted like a traffic signal, or even an elaborate system for sequentially checking the noise level in all channels as they become idle. One of the primary functions of such equipment is quickly to draw attention to improper practices which cause momentary or temporary interruptions or degradation to working circuits.

Since the report and control equipment is auxiliary to the primary purpose of the radio system, consideration of the needs for such facilities and their design is often not as thorough as is warranted for a high-quality, high-reliability system. Complete evaluation of the importance of the various options and inclusion of the features required for the desired system performance will generally pay good dividends.

SITE SELECTION

The major considerations in determining the choice of repeater sites have been discussed in the main body of this paper. The purpose of this section is to define in more precise terms what the sequence of events might be in choosing the route.

The first step, after the over-all system concept has been established, is to secure the available mapping information. When topographic maps are available, route layout men plan a tentative route taking into account such problems as frequency coordination, path profiles, and site accessibility. The first of these, frequency coordination, is a serious problem in the USA and it includes the study of existing frequency assignments, tower locations, and antenna systems to insure the minimum of intersystem interference. Intra-system interference is also a very real threat, and care must be taken that a route provides sufficient (5 degrees or more) angular staggering so that any "overshoot" propagation does not limit performance.

When a tentative layout has been decided upon, field crews are sent to check the sites chosen from maps. They check

elevation accurately with altimeters at the site itself, also at points along the path that might be critical from a clearance standpoint. The possible points of reflection are also checked and every effort is made to avoid flat reflecting surfaces such as paved roads, airports, and so forth. Then the availability of the land, power, and commercial length of road required is determined. A failure to meet all these conditions at any one location can cause the abandonment of several other sites which might be acceptable.

Because the cost of purchasing property, and constructing the necessary building, tower, power line extensions, and emergency power facilities involves considerable investment, path testing has sometimes been employed prior to permanent construction. This entails erecting a portable tower at each end of a proposed path and conducting a one-way propagation test. Towers are assembled from pre-cut sections, supported by guy wires, and erected in such a way as to permit the raising and lowering of transmitters or receivers and their associated antennas from the ground. Of course, means must

be provided for adjusting the antennas in both azimuth and elevation from the ground level.

All necessary cabling for control and measurement circuits is also provided so that ground personnel may be constantly apprised of the equipment's performance. The weight of a complete set of such equipment may be as much as 2 tons and may require special means of transportation. There is also the additional requirement of gasoline or diesel-driven alternators to provide power in cases where commercial power is not available. The use of low-frequency radio makes it possible to maintain two-way communication between test sites.

Since the path testing described above is expensive and the test duration is limited to relatively short periods, other methods of path surveying have been developed. The most successful one at present is the aerial survey. This method includes both photographic and radar techniques. Photogrammetric techniques call for relatively high-level flight (about 30,000 feet), with photographs taken at predetermined intervals. A picture may include an area approximately 5 miles in length and 2 miles wide. The time interval between successive photographs is such that each picture taken will overlap half of the preceding one. Using three-dimen-

sional methods of stereophotography, it is then possible to prepare profiles and topographical maps. This is done by drawing a line on the photographic strips between proposed tower sites. The specially designed photogrammetric equipment makes it possible to draw profiles with accuracies to within a few feet. The absolute elevations along the path relative to sea level can be established if some known elevations (bench marks) are present in one or more of the photographs.

The radar altimeter method of plotting path profiles has also been successful. This is done by flying a course at about 500 to 800 feet above the terrain. The altimeter is used to operate a high-speed recorder which plots the path while in flight. This method does not give absolute elevations relative to sea level unless it is related to some known point on the path. Actually, the absolute elevation is of little importance since only relative elevations are required for profile plotting.

The radar method can be supplemented by a method of oblique photography of critical points along the path. At those points where trees, buildings, or other obstacles are suspected, path-obstacle photography makes it possible to estimate their heights. Accuracies to within 2 or 3 percent are claimed for this method.

REFLECTIONS IN ANTENNA FEED LINES

The many contributing factors that limit the length and quality of a microwave system have been listed in the system description. One of the important contributors to the total distortion is the specific type of phase distortion caused by echoes in the microwave transmission lines. Discontinuities or mismatches in long transmitter or receiver feeds reflect a small amount of the signal energy which is reflected back and forth in the line and eventually arrives at the destination along with the major part of the signal that had not been reflected. The two or more signals are out of phase by an angle that is proportional to the additional distance that the reflected signal has traveled in the

transmission line. In any practical system the reflected signal is very small, but because it is a function of frequency and the modulated signal covers a wide frequency band, the reflected signal adds to the normal signal to create a nonlinear frequency versus phase characteristic. Delay distortion caused by these echoes will increase with the number and severity of the mismatches. In articles available in the literature, magnitude of the intermodulation has been provided in graphic form for most practical applications.

Echo distortion is important in the design of a long, high-quality system of the type considered here because so many other factors depend on it. In the initial

layout of the system, requirements such as channel capacity, reliability, system length, cost, and available spectrum are usually the first factors determining the actual form the system will take. When the choice of antennas and transmission lines must be made, they are determined primarily by the system capacity and the number of repeaters that will have to be placed in tandem. For example, if the ultimate r-f channel capacity is desired, the antenna system must have a sufficient front-to-back rejection to permit transmitting in opposite directions on the same frequency at each station. If ultimate quality per channel is desired, the antenna must have a low voltage standing wave ratio and the feeder must have a minimum of distortion-producing echoes.

A passive reflector system with its inherently short wave-guide runs is advisable for a system that does not require the ultimate in band utilization that the best tower-mounted antennas would provide. The passive reflector antenna system reduces wave-guide feeder echo problems. Mounting parabolas or horn-type reflectors atop a tower poses stringent requirements with respect to the VSWR of the feeders. Installation thus becomes more difficult and costly, and generally introduces greater echo distortion. The level of this type of distortion must be limited if one is to have an acceptable transmission quality. In a CCIR standard of not more than 7500 picowatts of total weighted noise in a channel referred to 0-dbm test tone for a 1550-mile circuit, approximately

1350 picowatts are allowed for the echo-distortion contribution. This distortion is random so that it is assumed to add as noise power. The average noise power allowed per feeder is 12 picowatts. Mismatches in feeder systems occur at almost every joint, bend, termination, filter, and source. In short wave-guide runs (under 25 ft.), the number of reflections and the distance between them are small, so small, in fact, that joints having a VSWR as high as 1.05 and terminations as high as 1.1 would still produce less than 1 picowatt of distortion noise power per antenna run.

These same high voltage standing wave ratios on a 200-ft. wave-guide run to a tower-mounted horn or parabola would produce over 200 picowatts of noise power for a system of the type required. To improve the quality of the feeder to a quality approaching that of the passive reflector system would require more expensive components throughout. It would also require more time and greater skill in making the installation. The greater expense of the tower-mounted antenna system is justified in cases where the extra radio channel capacity is required, but in this case the passive reflector system seems ideal.

Much has been written about feeder echoes and their effect on baseband noise. The following references may be useful:

MULTIPLE REFLECTIONS IN LONG FEEDERS, L. LEWIN, Wireless Engineering, July 1952
ECHO DISTORTION IN FREQUENCY MODULATION, R. G. MEDHURST, Electronic & Radio Engineering, July 1959.

RELIABILITY

The reliability of a microwave system depends on several independent factors and some correlated factors, the main causes of outage being those due to equipment failure and fading.

An equipment outage will occur in a system (with i-f switching and complete one-for-one equipment fallback) whenever two similar equipments fail over the same hop, i.e., both diversity systems fail.

The relationship $P = \frac{R(N+1)}{2} p^n n!$, where

P = probability of system failure due to all equipment outages,

R = number of repeaters in the system,
 N = number of regular paths per diversity path,

n = number of repeaters in a switching section,

p = probability of a single equipment outage,

can be shown to give accurate results for this type of system. The probability of a single equipment outage can be found from the mean time between a single equipment's failures and the mean time to repair a failure. Based on a mean time between failures of 2500 hours and a mean time to repair a failure of 2.5 hours, the probability of a single equipment failure is 0.001 and the probability of a failure in a 286-hop system with i-f switching at every hop is 0.000286.

It has been experimentally and statistically shown that short-term fading is basically Rayleigh distributed about a median level corresponding to the free space propagation level. It can be seen that, for a single path fading margin of 35 db in a 286-hop system with baseband combiners at 62 terminals (every 4.61 hops average), the probability of system failure due to propagation alone is 0.00016. This figure is obtained only when the equipment is in normal operating condition.

The probability of a hop being in a partially failed (diversity inoperative) state can be found from the binomial distribution laws. For the 286-hop system the equipment is normal for 56.33 percent of the time and partially failed for 43.64 percent of the time, the remaining 0.03 percent being total failure. Thus, for the 56.33 percent of the time that the equipment is normal, the probability of a system failure due to fading is $(0.5633)(0.00016)$ or 0.00009.

The situation when the equipment is in a partially failed state is a bit more com-

plex, involving the different lengths of time that exactly 1, 2, 3, 4, and so forth, up to 61 combining sections, are in a partially failed state. The exact location of a partially failed hop within a combining section is essential for a correct reliability figure. If on a 5-hop combining section one of the first transmitters is inoperative, the section will look like a single hop with no propagation diversity, in tandem with 4 hops with a parallel 4-hop propagation fallback. On the other hand, if one of the fifth receivers is inoperable, the system will look like 5 single hops in tandem utilizing no propagation diversity. Since it is equi-probable that any of the equipments is in a failed state, it is reasonable to take an average condition and call it representative. This type of section then can be placed in tandem with the other 60 combining sections which are operating normally, to find the probability of system failure when exactly one hop is in a partially failed condition. Similarly, two or more combining sections of this type may be placed in tandem with the rest of the system operating normally, in order to find the probability of failure for the system when exactly two or more hops are in a partially failed state.

The results for a 286-hop system, with i-f switching (equipment protection) at every hop, a fading margin of 35 db, baseband combining at each of 62 terminals, a mean time between single equipment failures of 2500 hours, and a mean time to repair a failure of 2.5 hours, are shown below

CALCULATION OF RELIABILITY

System failed due to equipment failures	0.00030
System failed due to propagation with equipment normal	0.00009
System failed due to propagation with equipment partially failed	0.00048
System failed due to all causes	0.00085
Reliability $1 - 0.00085 = 0.99915$ (99.915%)	

CALCULATION OF RELIABILITY (Cont'd)

Equipment:

System normal	0.5633		
		1 hop	0.3245
		2 hops	0.0924
System partially failed	0.4364	3 hops	0.0167
		4 hops	0.0025
		5 or more hops	0.0003
System failed	0.0003		
Total	1.0000		

Propagation (with equipment partially failed):

0.00046	Propagation with 1 hop failed due to equipment	0.00027
	Propagation with 2 hops failed due to equipment	0.00012
	Propagation with 3 hops failed due to equipment	0.00003
	Propagation with 4 hops failed due to equipment	0.00001
	Propagation with 5 or more hops failed due to equipment	0.00003

REQUIREMENTS FOR MULTIPLEX TERMINAL EQUIPMENT AND DERIVED VOICE-FREQUENCY BANDS

1. Telephone Channel Input and Output Impedance. 600 ohms balanced to ground. The degree of longitudinal unbalance shall be 50 db for frequencies 250 to 3600 cycles.

2. Telephone Channel Test Signal. 1000-cycle signal at minus 16 dbm at the input to the 4-wire send circuit.

3. Telephone Channel Output Power. Plus 7 dbm with standard channel test signal while meeting the distortion limitation.

4. Signal-to-Noise Ratio. The telephone channel signal-to-noise ratio shall be at least 60 db unweighted, with all other channels idle.

The telephone channel signal-to-noise ratio shall be at least 55 db unweighted, with all other channels loaded with a single tone at minus 26 dbm and at any frequency within the channel bandwidth.

5. Amplitude Frequency Response Characteristic. The telephone channel amplitude frequency response characteristic shall

not vary more than ± 1.0 db with 1000 cps as reference over the range of 250 to 3600 cps.

6. Harmonic Distortion. The telephone channel second or third harmonic distortion shall not exceed 5 percent (26 db below the fundamental) when measured, using an input of minus 16 dbm at any frequency such that the harmonics fall within the bandwidth

The telephone channel second or third harmonic distortion shall not exceed 1 percent (40 db below the fundamental) when measured, using a signal of minus 26 dbm.

Individual intermodulation products ($a \pm b$, $2a \pm b$, $a \pm 2b$, etc.) between any two frequencies (such that the products fall within the bandwidth) shall be at least 40 db below the combined level of minus 26 dbm when the two test frequencies are transmitted at levels of minus 29 dbm each.

7 Telephone Channel Frequency Displacement. The telephone channel (voice) frequency displacement without frequency lock shall not exceed 1 cps on an over-all system basis between the two v-f channel terminals going through four stations controlled by four independent base oscillators. All channels shall be capable of direct carrier frequency lock if required.

8. Envelope Delay Distortion. The delay distortion of the telephone channel shall be 1.0 millisecond maximum from 800 to

3250 cycles and 1.4 milliseconds maximum from 400 to 3580 cycles.

9. Baseband Input and Output Impedance. 75 ohms unbalanced.

10. Baseband Input and Output Levels. Output level shall be adjustable over the range minus 32 dbm to minus 45 dbm per channel test tone, and the multiplex equipment shall be able to accept and operate satisfactorily over this same range of input levels.

EXAMPLE OF ECONOMICS RELATING TO A MICROWAVE TRUNK SYSTEM

For evaluating the economics of a long trunk microwave system, it is convenient to introduce the concept of a "section" for use as a unit of measurement. Under this concept, a section is composed of one-half of two intermediate type terminal stations, plus the one or more intervening relay or repeater stations. A simplified sketch of such a section is included in the graph attached as Figure 1. If the section length is denoted as M miles and the number of

voicebands as N , the installed cost, including carrier multiplexing equipment, may be represented as follows

$$C = C_0 + C_1 M + C_2 N \quad (1)$$

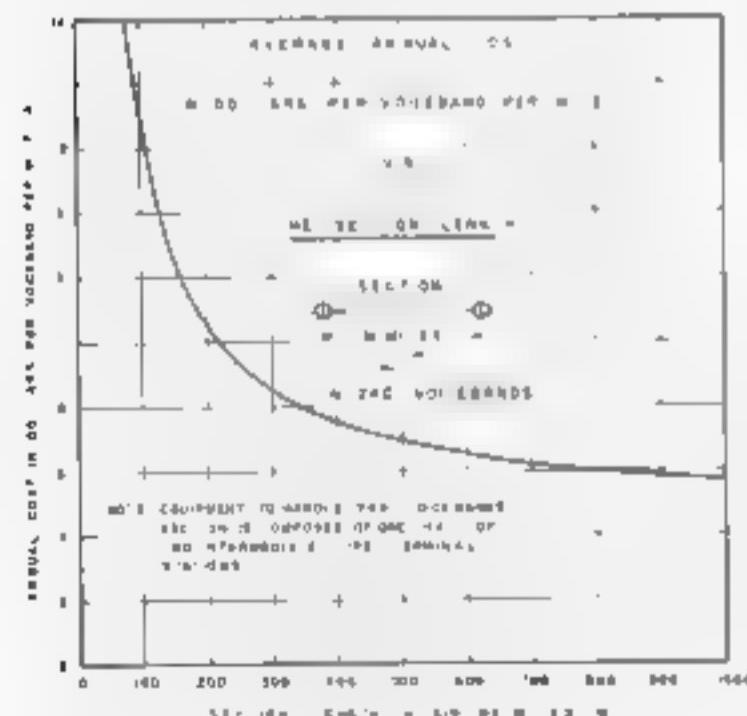
Similarly, related total annual charges may be expressed as:

$$A = A_0 + A_1 M + A_2 N \quad (2)$$

From estimates, it is possible to assign values to the various coefficients as shown in the following table:

Voiceband Group	C_0	C_1	C_2	A_0	A_1	A_2
1- 60	98,000	5760	1794	101,000	1020	142
61-120	113,000	5760	1794	102,000	1020	142

FIGURE 1 EXAMPLE



Data for Figure 1, showing average annual cost in dollars per voiceband per

rule, might be obtained by using the above coefficients, applied to a section equipped to handle 240 voicebands. In this case, equation (2) reduces to the form

$$A = \frac{A}{MN} \approx 4.25 + \frac{600}{M} \quad (3)$$

Applying the section concept to a long microwave trunk system comprising S sections of various lengths which add up to a total trunk distance of D miles, the total installed cost may be approximated by the expression:

$$C_T \approx C_0 + (C_1 + C_2 N) S + C_3 D \quad (4)$$

For $N = 120$ voicebands, equation (4) reduces to

$$C_T \approx 30,000 + 326,000 S + 5760 D \quad (4')$$

I. Typical Relay Station Estimating Schedule

No.	Item	Installed Cost	Annual Charges
1.	Site Acquisition, 4 acres	\$	\$
2.	Site Survey and Photogrammetric Work		
3.	Site Improvement		
4.	Tower Erection		
5.	Hut		
6.	Commercial Power or Primary Generating Equipment		
7.	Fallback Power Generating Equipment		
8.	Radio Equipment, Two 2-way and Point Locating		
9.	Antenna System		
10.	Spare Equipment		
11.	Test Equipment		
12.	Testing and Alignment		
13.	Maintenance Training		
14.	Automobiles for Maintainers		
15.	Total Capital Costs	\$	
16.	Annual Charges		
17.	Annual Maintenance — Labor		
18.	Operating Costs:		
	a. Power	\$	
	b. Telephone		
	c. Fuel		
	d. Tubes		
	e. Maint. Parts		
	Total Operating Costs	\$	
19.	Total Annual Charges	\$	

II. Terminal Estimating Schedule

A. Typical End-of-Line Terminal

No.	Item	Installed Cost	Annual Charges
1	Radio Equipment, Two 2-way and Fault Locating	\$	\$
2	Antenna System, including Waveguide		
3	Spare Units		
4	Emergency Power Equipment		
5	Test Equipment		
6	Furniture and Office Rearrangement		
7	Cabling and Remote Control Equipment		
8	Testing and Alignment		
9	Maintenance Training		
10	Miscellaneous		
11	Total Capital Cost . . .	\$	
12	Annual Charges		
13	Annual Maintenance, Labor (5 men)		
14	Operating Costs:		
	a. Power	\$	
	b. Telephone		
	c. Rent		
	d. Fuel		
	e. Tubes		
	f. Parts		
	Total Operating Costs	\$	
15	Total Annual Charges	\$	
B.	Typical Intermediate Terminal (Back-to-Back)		
6	Costs for End-of-Line Terminal (Lines 11 and 15)		
17	Additional Capital Costs for Back-to-Back Operation:		
	Radio Equipment		
	Antenna System		
	Spare Units		
	Office Rearrangement and Furniture		
	Cabling and Remote Control Equipment		
18	Total Capital Cost . . .	\$	
19	Additional Operating Costs		
20	Total Annual Charge	\$	

EXAMPLE

Estimated Installed Cost of a 500-Mile Radio Beam System

A. Capital Costs

1. Terminal Stations—2 @ \$	(from II, item 11)	\$
2. Relay Stations—17 @ \$	(from I, item 15)	
3. Carrier Multiplexing Equipment		_____

B. Annual Charges

1. Terminals—2 @ \$	(from II, item 15)	\$
2. Relay Stations—17 @ \$	(from I, item 19)	
3. Carrier Multiplexing Equipment		_____

Total \$

Note: Above costs provide voicebands to the 4-wire termination point but do not include cost of any telegraph, facsimile, data, or telephone terminals.



Edward G. Robinson graduated from Woolwich Polytechnic, London, in 1955 where he obtained the Higher National Certificate in Electrical Engineering. He has been with the Telegraph Company since 1945 and for the past six years has been concerned with the design, installation and testing of Telegraph and Power Equipment.



Western Union Equipment and Repair Shops in London, England, build and install power switchboards (above, left), make and repair apparatus and instrument parts (center), and inspect and test (right) a variety of telegraph devices employed in European landline and cable services.

EDWARD G. ROBINSON, Engineer, London

London Equipment and Repair Shops

THE London Equipment and Repair Shops are playing an essential part in the manufacture and installation of the modern equipment necessary to meet the particular needs of the European section of the Western Union International Department.

General

The London Equipment and Repair Shops are responsible to the European Plant Supervisor and are situated on one floor of a warehouse building close to Western Union House, London. On the same floor are the European Equipment Stock and Salvage Stock stores.

The activities of the two sections, of six men each, often are integrated so that, within the European section of the International Department, they manufacture equipment, install all equipment (of both European and American manufacture), and repair and overhaul all pieces of telegraph apparatus returned to Salvage Stock.

The Equipment section contributes to the manufacture of the larger items of equipment not requiring fine machine work and carries out most of the installation work, whereas the Repair section manufactures apparatus requiring fine machine work, repairs equipment, inspects

European Stock intake and does a small amount of installation work.

The small size of the sections involves very little administrative work. The cost of all manufacturing and installation projects is estimated in the office of the European Plant Supervisor. After the appropriate authority for an expenditure has been obtained the necessary instructions are passed to the sections by means of a Works Order, which details the work. At the same time the necessary drawings and specifications are issued from the office of the European Plant Supervisor, who also requisitions or orders the necessary material.

The work carried out by each man is logged, from which the labour cost is allocated and a close check kept on the progress and cost of the various current works in process. In the case of maintenance the same procedure is followed except that no capital expenditure authorisation is required.

Manufacture

The two shops are equipped with lathes, vertical drilling machines, a small welding plant and sheet metal press as well as the normal small workshop tools, so that a wide range of manufacturing processes may be undertaken. Certain minor spe-

cialized activities, such as painting and electroplating, are subcontracted to outside concerns. A general view of a portion of the Repair Section with lathes and vertical drilling machine is shown.

The Repair Shop has for many years manufactured precision electromechanical apparatus, beginning when a large number of small unobtainable parts for recorder apparatus were made. Prior to World War II considerable work was undertaken in the instrumentation of the submarine cable plough,¹ which was highly successful in burying submarine cables in the sea bed as protection against trawler gear, anchors, and so forth. The transducers carried on the plough, by which its precise behaviour was transmitted to the cable ship pulling it, were manufactured by the Repair Section. During the war the resources of the Repair Shop contributed to the general war effort when they manufactured telegraph instrument parts for the allied forces.

Since the war, in addition to making the more precise electromechanical parts for incorporation in the large units manufactured by the Equipment Section, the shops have produced much electronic equipment such as capacity-resistance bridges, time service units, landline terminal amplifiers and pulse-echo fault localisation equipment.² In addition to furnishing the latter for many of the cable stations and both cable ships of the International Department, they have recently made a batch of nine for another

large international communications company.

Occasionally the Repair Shop has been called upon to manufacture otherwise unobtainable spare parts for old equipment which is still in service.

A constant manufacturing task of the Equipment Section is the fabrication of



London Equipment and Repair Shops produce patching panels, channel switchboards and equipment such as this single/double current converter terminal relay rack.

operating tables for use within both Western Union and patrons' offices. The latter are normally of a standard basic design but almost invariably have to incorporate some modification to suit the particular requirements of the customer for whom the table is intended. Usually one man is responsible for the manufacture, installation and testing of each table and on the average some 25 operating tables are installed in or withdrawn from customers' offices each year.

The combined manufacturing resources

of the two sections have, in the past 10 years or so, produced distributor tables, cable and underground patching panels, telegraph and cable channel switchboards and distributing frames, power switchboards and landline terminal equipment.

Typical examples of this work are shown, including a power switchboard in the course of construction and a single/double current convertor terminal relay rack during and after manufacture.

Installation

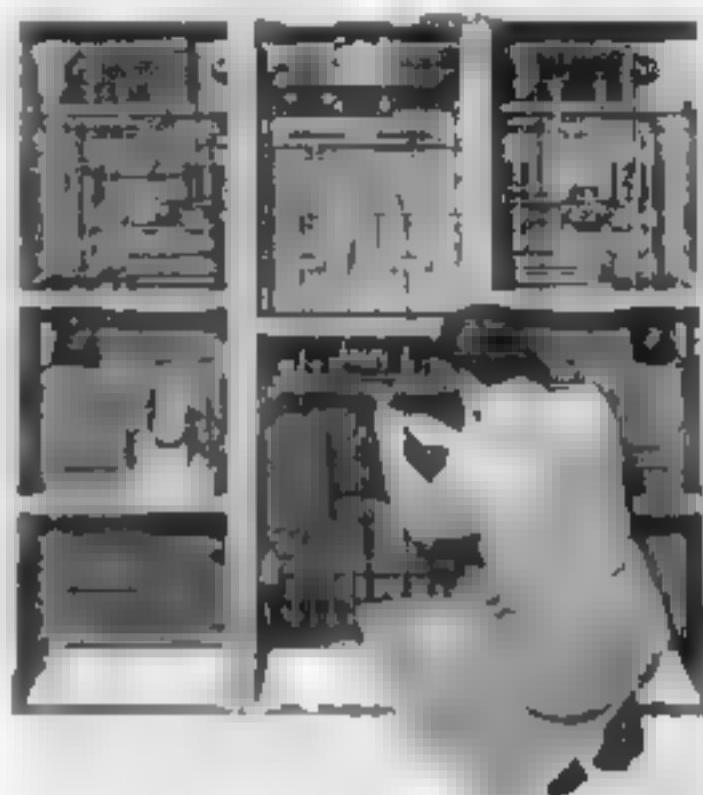
The Repair Shop is responsible for the installation of Desk-Fax equipments to patrons' offices. The Equipment Section, on the other hand, is responsible for all other installation work. In the past few years much installation work has been carried out in the Penzance and Valentia cable stations in connection with the insertion of submerged repeaters in the transatlantic cables and the consequent additions to the cable terminal apparatus. The Equipment Section has also refitted both cable stations and all the Western Union Continental European offices during the postwar modernisation programme. In the past two years or so a start has been made on the installation work connected with the improvement of the main operating floors at Western Union House, London.

The Equipment Section has also installed new power switchboards and prime movers at the Valentia and Penzance cable stations using, in the main part, standard equipment of American and British manufacturers. A new power switchboard recently was installed in the Power Room at Western Union House, London.

Inspection, Overhaul and Testing

All telegraph equipment purchased for European Stock is inspected and tested by the Repair Shop. However, the greater proportion of their inspection and repair activities is centered on European Salvage Stock. This is apparatus and equipment which is withdrawn from field service either because it is surplus to requirements at the particular station or because it is in need of major overhaul and repair. The Repair Shop inspects and,

where economically justified, repairs the telegraph apparatus. After repair it is tested at the Test Bench as shown and placed in European Stock for reissue into service as required.



Rear view of power switchboard for Western Union House, London, shown also in heading illustration

Occasionally the Repair Shop is called upon to undertake repair work for outside concerns. A recent example of this was the overhaul of the two 5-channel multiplex distributors for the U.S. Army. This involved the complete mechanical refitting of the distributor and the machining of four multiplex faceplates some 18 inches in diameter.

Staff

This being a small unit covering a wide range of activities, from the overhaul of a Desk-Fax machine to the installation of an 80-hp diesel-alternator set, each member of the two sections trust receive as wide a training as possible. To this end the junior members attend courses in workshop practice and theory at technical colleges and interchange between both sections during their first few years with the company.

References

1. THE SUBMARINE CABLE FLOW C. S. LAWTON 4-7 TRAFFIC 8 June 1939
2. FAULT LOCALISATION ON A MARINE CABLE R. A. GOODMAN and D. A. PARKER *Marine Engineering Technical Review*, Vol. 11, No. 3, July 1952

Technical Associates of Western Union—IV

Technical Operations, Incorporated (Tech/Ops)

Technical Operations, Incorporated, is a research and development firm with main laboratories in Burlington, Massachusetts. The company employs approximately 300 people, of whom half are located in the main laboratory and the remainder are in the branch research offices at Fort Monroe, Virginia, Stamford, Connecticut; and Washington, D. C. The technical staff is composed of about 150 professional scientists and engineers. Approximately 25 percent have doctorate degrees; 25 percent have master's degrees; and 50 percent have bachelor's degrees. The company is organized into groups working in the fields of physics, electronics, chemistry, applied mechanics, systems analysis, and computing technology. These groups are supported by a well-staffed and equipped laboratory and model shop.

Projects under investigation by Tech Ops range from a study of ballistic defense mechanism in the 1970-1980 time period to the laboratory simulation of the effects of nuclear weapons in outer space.

Tech Ops' experience has included participation as a team member of several major U. S. Air Force systems studies, including the "Weather Observing and Forecasting

System"—433L—for which Tech Ops has responsibility for systems analysis; the "Air Force Command Control System"—473L—for which Tech Ops has responsibility for computer programming; and "ComLogNet," a highly automated electronic data and communications switching network, for which Tech Ops is consultant to Western Union and acting in an advisory capacity for both programming and systems analysis. Also, under Air Force sponsorship, Tech Ops has devised, for use on an IBM 7090 computer, a series of simulation models for two-sided global aerospace operations.

Tech Ops has been active in the field of nuclear and space physics for ten years and is familiar with all aspects of nuclear weapon effects—under water, on land, in the air and in outer space. They have investigated the implications of nuclear warfare on missile implementation and prepared mathematical models capable of simulating these conditions.

Tech Ops' chemistry group is involved in many areas of research, including the investigation of unique photographic materials which are insensitive to radiation and, therefore, capable of use in surveillance systems located in outer space.



Dispatching

It is common knowledge that train dispatchers control the movement of freight and passenger trains in order to maintain service during both normal and extraordinary conditions. Dispatchers are employed to coordinate the assignment of buses, trucks, taxicabs and service crews, to control the flow of oil and gas in pipelines, to meet the ever-changing demands for electric power and lighting, and so forth.

In Western Union, dispatching (circuit dispatching as distinguished from local dispatching of maintenance forces) is essentially a plan for the day-to-day coordination of effort in protecting the company's many telegraph services, at all times and under all conditions. It provides for the best disposition of available facilities for maintaining continuity of leased wire service and the protection of message traffic during serious emergencies and periods of congestion, and for the full and proper use of facilities required for special events and extraordinary situations.

The Necessity

In order better to understand the purpose of dispatching one should comprehend the conditions leading up to its establishment. Prior to 1914, when the Western Union dispatching system was established, intercity circuits were on open wire lines. Practical carrier telegraphy was unknown. Essentially, each

principal telegraph office was a circuit-terminating point and probably, also, a repeater station on other circuits passing through it. Transcontinental message traffic and much of the traffic between widely separated cities was relayed by Morse operators at intermediate offices. Responsibility for circuit protection and the movement of traffic was more or less local



Figure 1 - Poles and wires down in a severe ice storm

in nature and carried out on an autonomous basis.

When a circuit failed between two points due to wire trouble and a spare wire was unavailable to effect a substitution, traffic was relayed through another office. This action usually followed an inquiry sent to the alternate office, followed by a favorable reply, to avoid traffic congestion in the event that the alternate office also was "down" to the same point. During severe and widespread wire prostrations (see Figure 1), alternate routes often did not exist and traffic could not be moved for long periods of time.

Confusion was not uncommon during such emergencies. Through lack of infor-

mation and coordination a large volume of messages sometimes accumulated at a stricken office or was relayed to others in similar circumstances. Occasionally, traffic was routed back and forth between two or more isolated offices, each one depending on the other's ability to dispose of it. Not infrequently three offices were involved in three-cornered routing. The conflicting efforts of several large offices to re-establish communication during the Dayton flood (March 25-27, 1913) is an example that will not be forgotten by the old-timers involved.

Lack of comprehensive information as to general conditions and possibilities of restoration often resulted in major relay offices ordering emergency facilities from railroads and telephone companies in situations where Western Union facilities in other territories were available that could have been patched together to restore service had this availability been known. Duplication and waste of effort, unnecessary expense and heavy traffic delays resulted from such situations.

"Sporting Chiefs", assigned to certain large principal offices, had the responsibility to provide circuits for special events. These requirements were often very heavy—radio and television coverage did not exist. Under pressure to set up newspaper circuits for such important events as World Series Baseball, boxing matches, political campaigns, etcetera, and especially when they coincided with severe wire prostrations, confusion and serious traffic delays sometimes occurred when Sporting Chiefs seized circuits or circuit sections to meet press requirements. Not infrequently, facilities in a particular section were "named" for such purposes by more than one Sporting Chief. Again, through lack of information and direction, interoffice conflicts occasionally were unavoidable and service suffered.

Another serious lack of coordination existed whenever a major relay office head (Chief Operator) decided to restore a failed circuit to an adjacent office by pre-empting a wire already in service in an equally important, or perhaps a more important circuit repeated at his office. For example, a Pittsburgh-Columbus

wire working in a New York-Cincinnati circuit might have been taken to restore a failed Pittsburgh-Columbus service if there were no spare wires between Pittsburgh and Columbus. Whether or not the longer circuit should have or could have been diverted to another route, whether or not the local need justified interrupting the New York-Cincinnati trunk, whether or not the Pittsburgh-Columbus circuit could have been set up via another office, and whether or not an alternate outlet (such as Cleveland) could have been provided for Pittsburgh-Columbus traffic, are questions which probably the Pittsburgh Chief Operator could not have intelligently decided because full knowledge of all conditions and possibilities was not available to him. If, due to existing conditions, the New York-Cincinnati circuit had been the only link to the midwest in service at the time, it probably should not have been disturbed. In periods of severe wire prostration, lack of coordination often led to serious consequences.

Obviously, some form of control was necessary. The first step taken in this direction was the establishment of "planning" or "control" offices. Accordingly, Buffalo placed and controlled all facilities to Cleveland; Pittsburgh acted as the control office to Cleveland, Columbus and Cincinnati, and so on. This plan improved conditions somewhat but failed to bring about the desired results. It appeared that some form of centralized direction over these control offices would lead to further improvement in day-to-day operation.

With this in mind the territory between Minneapolis, Omaha, Kansas City and Dallas, and extending west to the Pacific Coast, was selected as an area for a trial of centralized control. Under this plan, day-to-day control was centralized in an "Overland Chief" located at Chicago. Principal offices in this jurisdiction were instructed to report all facility failures and changes, traffic congestion and delays, to the Overland Chief. Information furnished the Overland Chief by field offices enabled him to give full consideration to both local and general viewpoints in the handling of wires, circuits and traffic. Thus, the objectionable features of inde-

pendent action on the part of local forces were minimized in favor of what was best for the territory as a whole. This was another step forward.

The Dispatching System

Centralized control proved so effective that in 1914 it was extended to include the entire system. The plan became known as Dispatching, with bureaus established at New York and Chicago, in each case headed by a Dispatcher reporting directly to the General Office and having a specified territory under his jurisdiction. As in any such venture upheaval often comes before progress. Objections were many. Local prerogatives had been usurped. But soon, responsibilities were clarified and cooperation followed. It was not long in becoming evident that the basic principle of dispatching is sound and that it would stand the test of most exacting pressures.

Such a test was met in the several years which followed. By 1917, when the United States became engaged in World War I, uniform practices had evolved. A direct circuit between the New York and Chicago Dispatching Bureaus and into the General Office had been established. Routine hourly reports of traffic conditions at all major offices made it possible to minimize congestion and delays. Field action to recover from the effects of storms, wrecks, fires and other catastrophes was expedited through dispatching coordination. The systemwide protection of circuits, the orderly planning for special events, and the control of sharply increased wartime message loads repeatedly confirmed the indispensability of dispatching.

In the few years following, improvements in the telegraph industry reflected the great demands of war. The trend to replace Morse trunks with automatic start-stop circuits and multiplex systems, which began about 1916, was accelerated during the early twenties. There was great expansion.

Dispatching practices underwent very little change, however, since they had been established on fundamental principles not altered by the volume of the telegraph load or the method of operation.

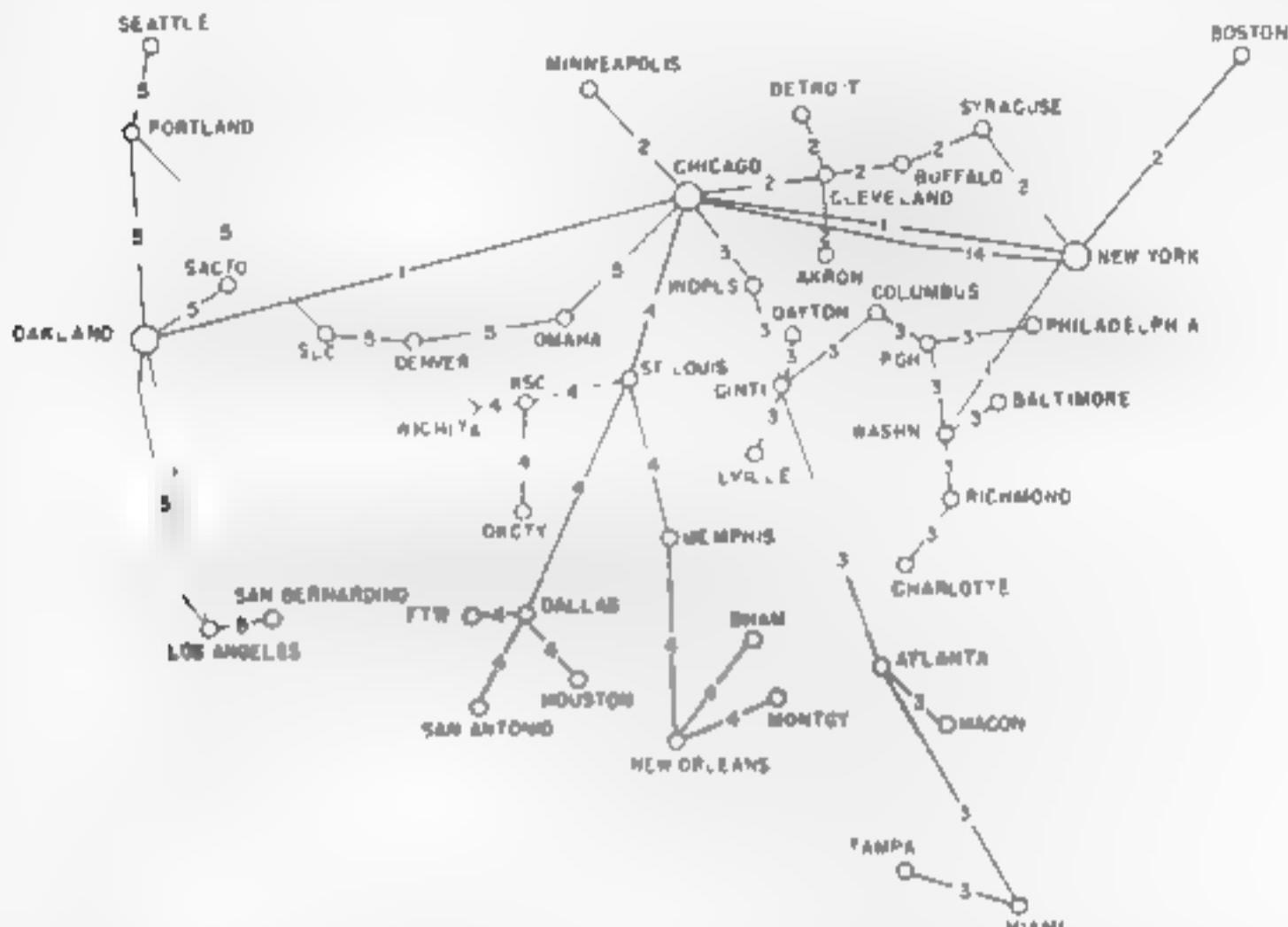
General instructions (many will remember Traffic Circular Letter 28-B), issued in 1922, formalized these practices and remained in effect for nearly thirty years.

In November 1925 a dispatching subbureau was established at Atlanta and in December 1929 subbureaus were set up at Dallas and San Francisco. Each unit assisted its controlling dispatching bureau in providing and protecting service in the outlying part of the latter's territory. Atlanta (AF) reported to New York (DS). Dallas (DU) and San Francisco (DF) reported to Chicago (DP). The San Francisco unit was moved to Oakland in the late forties when the Oakland reperforator switching center was established.

In 1948, dispatching was made a responsibility of the Plant Department. Dispatching functions changed considerably—but not in principle—during the next decade as a result of the modernization program and the rapid growth in the number and extent of Western Union's leased wire services. Except in extraordinarily serious emergencies, the network of interconnected reperforator offices now permits high-speed alternate as well as direct routing of message traffic on existing trunks without dispatching assistance. Circuits which interconnect major cities and bundling points are now on carrier systems. The number of those assigned to microwave facilities is growing fast. Great distances are spanned without intermediate relay points. Physical intercity circuits are, in general, limited to those serving small tributary points, some tie lines and services extending beyond local distribution areas. The number of leases has more than quadrupled. Many of them are half-duplex multiway networks serving several cities. Some are nationwide in coverage. A large number of leased circuits are connected to automatic switching centers operated by the patron. Data processing by telegraph has become commonplace. Testrooms are in direct contact with our customers, who are exacting in their demands for service continuity despite many complexities not encountered in the past. All of these factors have affected dispatching requirements and activities.

One outgrowth of this period of change and expansion was the faster and more direct contact by the dispatching bureaus with outlying offices made possible via long haul carrier facilities. Then, too, the greater diversification of nationwide activities, faster travel, military requirements, higher standards of service continuity and

number of interarea and intra-area test wires have been established to meet local-territory circuit-handling demands and provide alternate connections between the larger points. Many of these circuits also are terminated in one of the dispatching centers. All test and dispatcher circuits are equipped for teleprinter operation,



Pittsburgh, Baltimore, Philadelphia, Washington, Richmond, Atlanta and Miami. W4 serves such southwestern points as Kansas City, St. Louis, Memphis, Montgomery, Birmingham, New Orleans, Dallas, Houston, Ft. Worth and San Antonio. W5 serves Omaha, Denver, Salt Lake City, Seattle, Portland, Oakland, Sacramento, Los Angeles and certain other western points. W14 interconnects the New York and Chicago Dispatching Bureaus exclusively.

Ordinarily, field offices communicate with one another via secondary test wires or on idle channels or wires between them. This avoids congestion on primary test circuits. For example, Richmond and Atlanta normally communicate on W24, the New York-Atlanta test wire. When one of the connections on a secondary test circuit is New York or Chicago, it may be brought into the dispatching bureau. Similarly, some of the test circuits in the far west are brought into the Oakland dispatching subbureau (DF).

Offices not connected to a common secondary test wire may be on the same express circuit; Washington and Miami on W3 is a case in point. When two major points are not on the same express circuit and have no secondary means of contact, the communication is relayed. Cleveland (on W2) and Seattle (on W5) are typical points. In this case the normal relay would be at DP Chicago. A major office relays testroom messages to and from an office having no access to an express test circuit or a secondary connection to the point desired, for example, information from Roanoke (on W24) destined to Miami (on W3) is relayed at Richmond (on both W24 and W3). In some cases, of course, a circuit-to-circuit relay at DP Chicago also is necessary, as in the exchange of communications between Boston (on W2) and Roanoke (via Richmond).

Obviously, a certain amount of relaying is unavoidable. All points which must communicate with one another in maintaining a nationwide network of private wire services cannot be assigned to one large systemwide test and dispatcher circuit. Such an arrangement would lead to congestion and delay.

In sections where the message load between testrooms is particularly heavy, additional test wires are established. W12 interconnecting New York, Philadelphia, Baltimore, Washington, Pittsburgh, St. Louis, Kansas City, Omaha and Denver is an example. Auxiliary test circuits or so-called talk circuits are set up from time to time to meet special requirements. For example, a temporary talk circuit may be necessary to coordinate the testing and starting of a large switching system.

Facilities, Circuits and Services

Before describing dispatching activities, it would be well to note the very important distinction between facilities, circuits and services. These terms are defined as follows:

A facility is a single-section of wire or a carrier channel ready for connection to (1) terminal or repeater apparatus or (2) to another wire or channel to make up a multisection telegraph circuit. The term is also used collectively in regard to a system of integrated component blocks, bands or channels.

A circuit is the over-all electrical path (whether it be via a single-section facility or a number of interconnected facilities, together with the necessary repeater and terminating apparatus) over which service is provided between the terminal offices.

Service is the use to which a telegraph circuit is put.

A simple and uniform method of designating facilities, circuits and services is essential. Let us first consider the designation of facilities and the application of these designations. In general, we have facilities which provide for a multiplicity of circuits thereon and those on which only one circuit operates. A microwave system is designated by the prefix RB. RB10, for example, is one of the two "radio beam" systems between Cincinnati and Chicago. A voice-frequency band derived from this system will have a sub-number such as RB1007. The half band derived from a WU type WD-1 one-band carrier system will be designated WD780, using the Dallas-Waco system as an example. VF bands derived from WU type E

(one-band), type F (two-band) and type G (four-band) systems are designated as E985, F401B and G311D, respectively, referring to a typical band in each case. On leased VF bands, other designations are used. Typical designations are WF1061, 8WF3 and VF637.

VF bands may, of course, be patched together. Ordinarily, a total of 20 narrow-band channels can be derived from a VF band. It is common practice to divide VF bands into two subbands in order to provide flexibility of assignment and operation. For example, nine channels may be required between Portland and Helena,

another subband, held unassigned, or connected to a group of channel terminals. In the latter case, the group of up to 10 carrier telegraph channels (CTC) is known as a carrier channel group (CCG) and given an identifying number. In the example above, CCG478 is the 9-channel group assigned to Portland-Helena service and may be referred to simply as group 478. Carrier groups may, of course, be moved from one subband to another (on the same or another carrier system) as conditions require.

Individual channels are identified with the group of which they are a part. Thus,

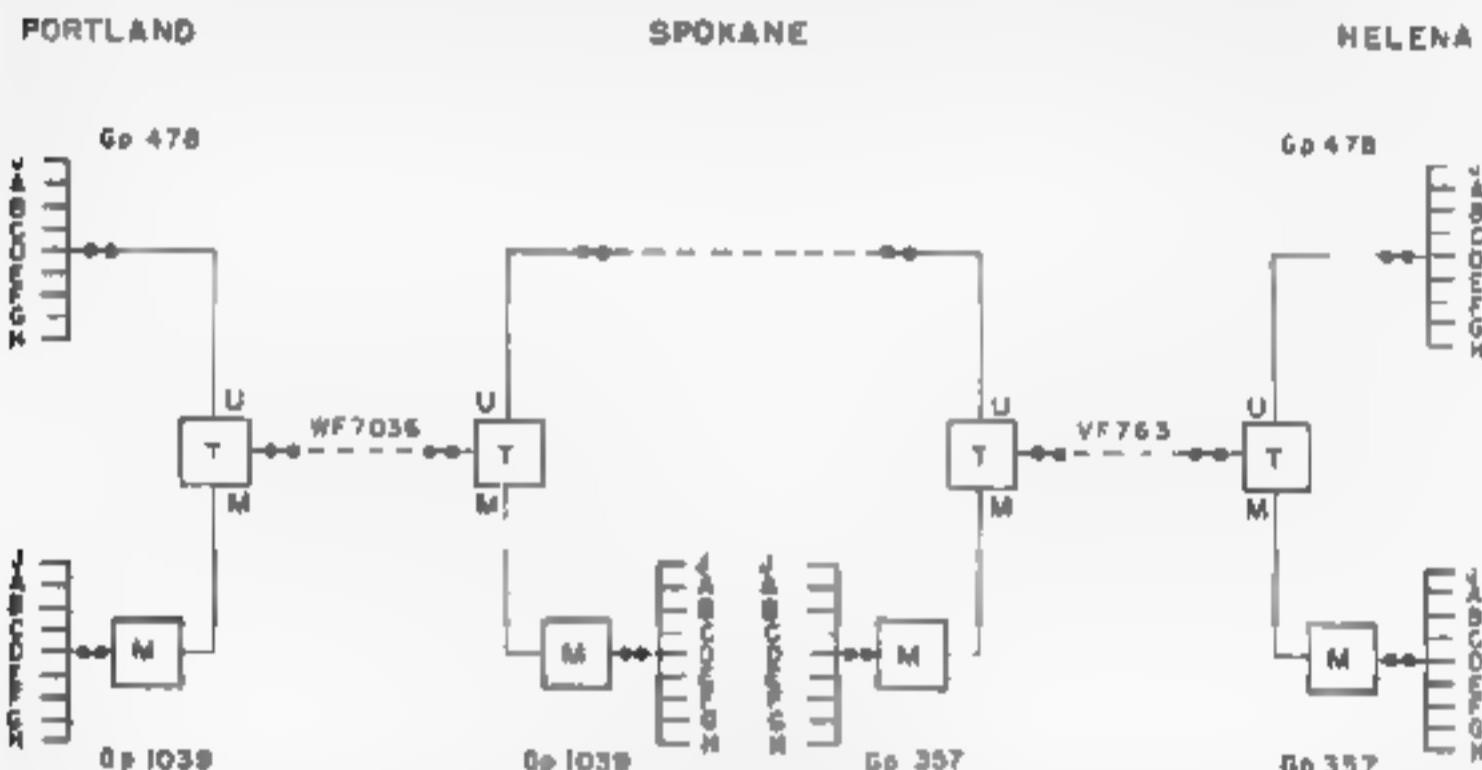


Figure 3. Derivation and patching of subbands

nine between Portland and Spokane and nine between Helena and Spokane. Two, instead of three, VF bands may be used by the assignment of modulating equipment at Spokane, the intermediate point, to separate the bands to Portland and Helena into two subbands each. The arrangement is illustrated in Figure 3.

Subbands are designated as U and M, respectively, for the unmodulated and modulated subbands. In this example, WF7036U and VF763U are patched together at Spokane to establish a Portland-Helena facility and WF7036M and VF763M are terminated at Spokane.

A subband is utilized in one of three ways. It may be operated in tandem with

CTC 478D is the fourth channel in the Portland-Helena group mentioned above and, as such, operates on a midfrequency of 975 cps as do all other narrow-band D channels. Since carrier legs are independent of carrier frequency they can be patched indiscriminately to repeaters or local drops, or operated back-to-back to other channels.

Physical wires are numbered and associated with a route designation. B&O 205 is typical. At times two wires are patched at a minor test office or junction point, in which case the facility may carry a double number such as L&N 210-278.

Intercity circuits (the over-all electrical path over which service is provided) are

given permanent assignments to specific facilities by the Circuit Layout Engineer. Typical, for example, is a leased circuit designated as X183 assigned to Fresno (CTC) 1160H Bakersfield 668E Los Angeles 1218A Santa Barbara, with serv-



Figure 4. Circuit X183 assigned to tandem sections.

ice drops at Fresno, Bakersfield and Santa Barbara and a back-to-back channel patch at Los Angeles. In this circuit, the facilities operate in tandem, as illustrated in Figure 4. BC8 is an example of a circuit made up of a combination of tandem and hubbed sections (see Figure 5), the assigned channels being New York 262H Syracuse 858H Utica, Syracuse 862H Watertown, Syracuse 870C Rochester 788A Buffalo 1078D Detroit. As indicated,

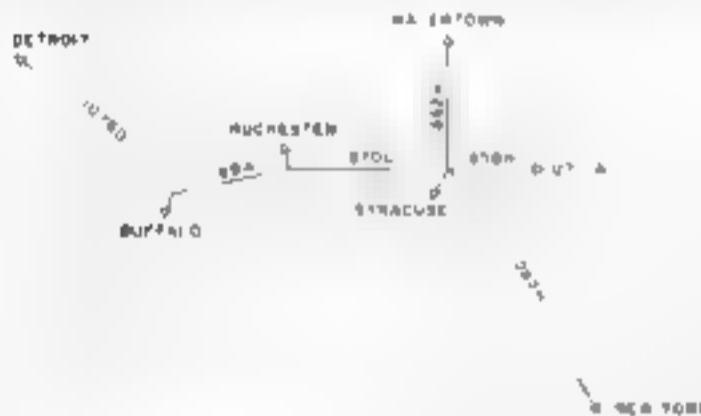


Figure 5. Circuit BC8 showing interconnection of tandem and hubbed facilities.

Syracuse is the hubbing point. Some leases are very complex and widespread networks and may employ a combination of carrier channels and physical circuits.

In some cases a circuit utilizes an entire VF band or several of them in combina-

tion. AFX109 is typical. Here the circuit is made up of a number of VF bands and hubbed at certain strategic points.

As stated before, service is the use to which a telegraph circuit is put. On the New York-Detroit circuit (BC8) referred to above, BC8 identifies the service as well as the circuit when the assigned facilities are in use. Use of the common designation is very helpful in day-to-day circuit handling. However, the association does not apply when the service must be diverted to other facilities. When this is done BC8 identifies the new circuit arrangement. The vacated portion is then handled as one or more facilities having no associated circuit designation. For example, if BC8 is temporarily brought into New York directly from Buffalo on 273B, a spare channel, in order to release New York 262H Syracuse to meet some special event requirement, 273B becomes a part of BC8 while 262H may be assigned temporarily to some such service as 3rd Syracuse-NP New York, as shown in Figure 6.

Typical Problems

The protection of service, under all circumstances, is a constant challenge to the dispatchers. Not a day passes without incident. Emergencies, to dispatchers, are commonplace. Extra-circuit demands, occasioned by growth and change and those required for special events, must be planned for and met along with all other activities. The highest degree of coordinated effort is necessary. Some of the situations confronting the dispatchers, and how these problems are met, should be of interest. However, because of the almost inexhaustible possibilities, only a few typical ones are used as illustrations.

The situation usually encountered is where facilities are needed to place additional circuits or circumvent trouble but none are available within the immediate territory affected. The term "available" should be explained. Certain spare channels are assigned for the exclusive use of the Dispatcher and T&R (testing and regulating) forces. These channels are

designated as T&R Service channels. Other unassigned channels may be spare. In addition, channels assigned to working circuits during the day may be idle at night (although for several reasons it is best not to disturb them). It is in the best



Figure 6. Designation of circuits on irregular facilities

interests of the service to delegate as much latitude as possible to the field concerning the use of spare and idle facilities. With this in mind principal testrooms are to initiate action in case of carrier channel and physical wire failures to restore service to working circuits by use of spare and/or idle facilities, subject to certain precautions. One of these precautions is that the Dispatcher is to be notified promptly when spare or idle facilities between principal offices are placed in service. Such notification is essential because the Dispatcher must often establish circuits to meet emergencies and special event requirements which may be unknown to the office wishing to utilize certain spare or idle trunk facilities. Use of spare and idle facilities at bundling (carrier concentration) points having an outlet to only one major office does not have to be reported to the Dispatcher except when due to extraordinary conditions and when the use may be prolonged.

When facilities are not available, as described above, in an affected circuit section the Dispatcher is asked for assistance. Insofar as possible, he then endeavors to reroute the interrupted circuit or reassign another so as to release a facility on which the interrupted circuit may be placed. Suppose, for example, that X917 is assigned to New York 1069A Albany and

that it fails, with no T&R Service channel or spare available between New York and Albany. Knowing that New York 198F Boston and Boston 274C Albany are spare, the Dispatcher orders Boston to patch them together. Using the office calls involved, the order would read: BQ PUT 198F NQ TO 274C AB FOR X917 DS New York and Albany would then meet on the rerouted circuit and move the X917 terminations to it from NQ 1069A AB. Upon being recovered, NQ 1069A AB becomes a spare. The handling is illustrated in Figure 7. X917 would not be "set regular" until after service hours, in order to avoid any momentary outage which might occur if this were done during business hours.

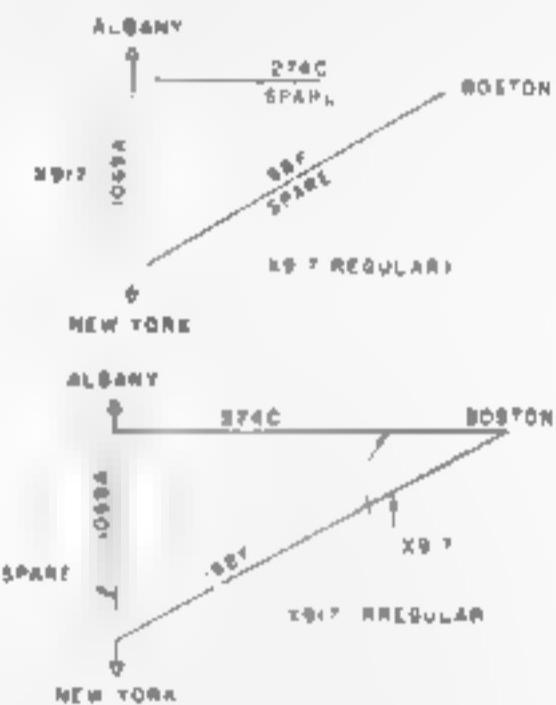


Figure 7. Temporary rerouting of Circuit X917

A similar situation, involving carrier facilities, would exist if Chicago (CQ) WF7093 Cleveland (CV) fails and there is no direct substitute. Assuming RB1010 (Cincinnati-Chicago) and 16WF510 (Cincinnati-Cleveland) to be spare at the time, the Dispatcher would order Cincinnati (JQ) to patch them together. The order would read: JQ PUT RB1010 CQ TO 16WF510 CV FOR CHGO-CLEVE SVC DP

If facilities in the general area of the need are not available, the Dispatcher does not hesitate to make any long-haul patches which will restore circuit con-

tinuity. From a dispatching standpoint, an Oakland-Los Angeles circuit or VF facility established via New York or Chicago is just as serviceable as one on a direct Oakland-Los Angeles route.

The same is true of subband patches. For example, group 301 (St. Louis-Dallas) might be restored, if failed, by way of Atlanta. Ordinarily, direct replacements are not available between the cities affected by a serious emergency and, therefore, emergency bands are obtained to other points, where they are patched as necessary to bridge the interrupted section or sections. Typical of such action would be the Dispatcher's order for an emergency VF band between Cincinnati and Chattanooga to make good group 600 (Cincinnati-Nashville) and group 605 (Cincinnati-Chattanooga), assigned to WF3089 (Cincinnati-Nashville), should this band be "lost". As shown in Figure 8, the Cincinnati-Chattanooga group is restored on Emergency VF1M and the Cincinnati-Nashville group on Emergency VF1U and 80WF3U. Group 607 (Nashville-Chattanooga) is unaffected and, therefore, undisturbed.

Emergency band or group patching via alternate facilities is simpler and faster than individual circuit handling and, for this reason, is the preferred method. It is also more economical. Of course, when no alternate facilities are available for band or group restoration, the Dispatcher and the testrooms involved collaborate in making the best use of available channels to circumvent the affected territory.

It is possible, although infrequent, that a severe flood or ice storm, hurricane or some other extraordinary cause may prostrate all communications facilities serving a community and isolate it completely. Under such conditions, considerable effort would be required to "get the pattern" of the total failure, locate and repair damage on an emergency basis and establish the first few avenues of communication into

the stricken area. The Dispatcher is, of course, informed of intercity facility shortages and recoveries and given condition and progress reports. With such information, he can order circuit rearrangements to divert working circuits from the trouble zone and in this way spare a limited number of facilities into that area for

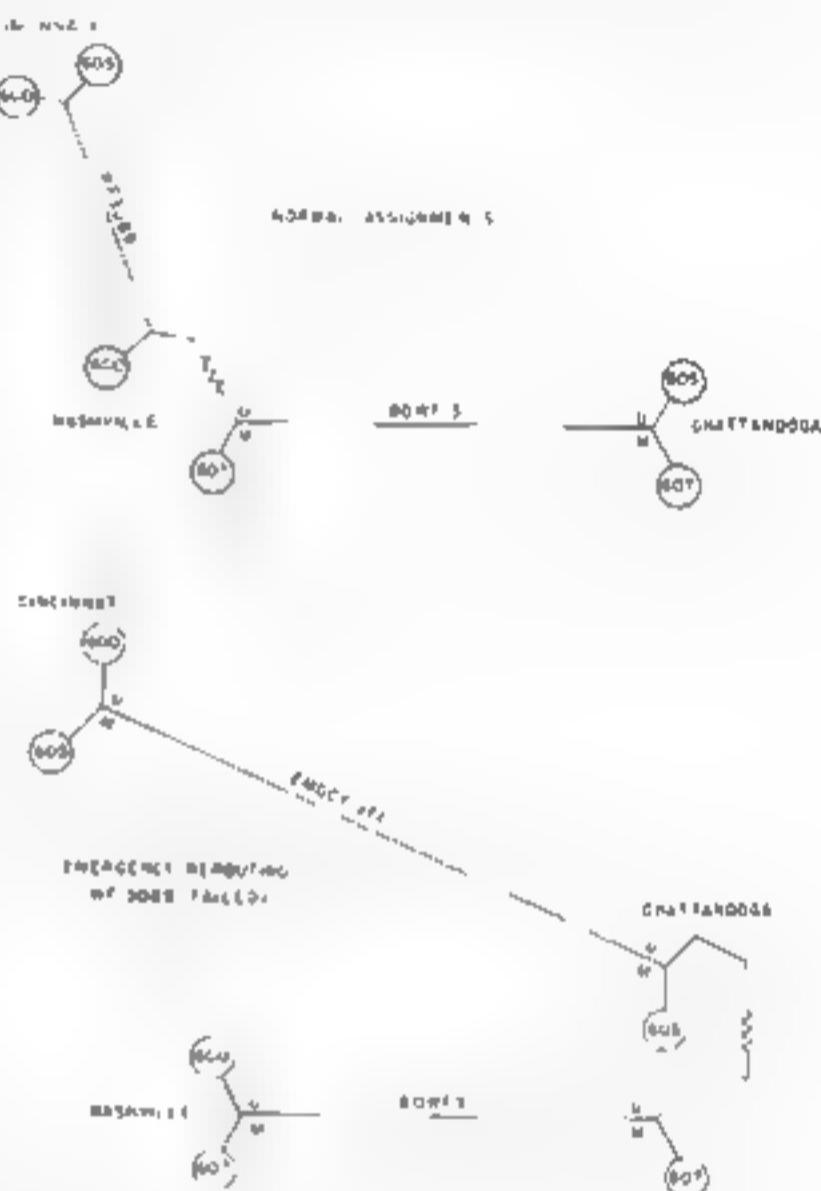


Figure 8. Routing of carrier groups via emergency VF band

immediate use, reestablishing other services as normal routes are made good.

In such circumstances, the emergency message load to and from loved ones in the disaster area and circuits required by relief organizations and for a number of other urgent reasons may necessitate additional circuit terminating equipment and technical and operating personnel at some nearby point or points. The Dispatcher coordinates the joint efforts of one or more testrooms in pressing regained facilities into service at the earliest possible moment. Because of modern and

diversified facilities, complete isolation of a large city is a rare occurrence indeed and, then, under most extraordinary conditions and usually for a relatively short interval of time.

Emergencies occur, of course, which do not isolate an office but are serious in their effect on service. Today, with high priority services, data transmission and other complexities, even momentary interruptions can be serious, especially when a multiplicity of circuits is involved. Contingencies are comprehended, however, and all reasonable steps taken to insure service continuity.

Grouping, Diversification and Triangulation

The Dispatcher devotes a major portion of his time to keeping abreast of the ever-changing network of permanently-assigned circuits and devising means of protecting service. With few exceptions, such as in the case of storm warnings, service interruptions cannot be foreseen. They must be dealt with as they occur. Much can be done, however, in arranging circuits so as to minimize their effect. Three such methods followed are grouping, diversification and triangulated protection.

Grouping pertains to the assignment of circuits according to service hours and other pertinent factors. For example, 60 circuits between Atlanta and Birmingham

may be assigned to three VF bands of two subbands each. If half (30) of these circuits are in continuous service and the other half close at various times from 500P to 700P Monday-Friday, it may be possible to assign all the AO (always open) circuits to three groups and the daytime services to the remaining groups. Obviously, three groups then become idle during the night and are available for other service, including emergency use. If two day-service-only groups are assigned to a band, the entire band becomes spare overnight. A large and flexible network of facilities thus becomes

available for emergency protection at nights, on holidays and over week ends.

As the term implies, diversification pertains to the separate routing of two or more circuits, in whole or in part, to avoid the possibility of simultaneous failure. Certain limitations exist which often make it difficult and sometimes impossible to achieve diversification. Among these is the extent to which alternate facilities are available. Service hours and circuit operating speeds also must be considered. The relative importance of one or more of several circuits leased by a customer is a major factor, especially when they converge in a switching center.

To be completely diversified, a circuit must have duplicate terminal apparatus and operating equipment and avoid all carrier systems, cable routes, local distribution facilities, customer-owned cables and power supplies, and so forth, traversed by another circuit or group of cir-

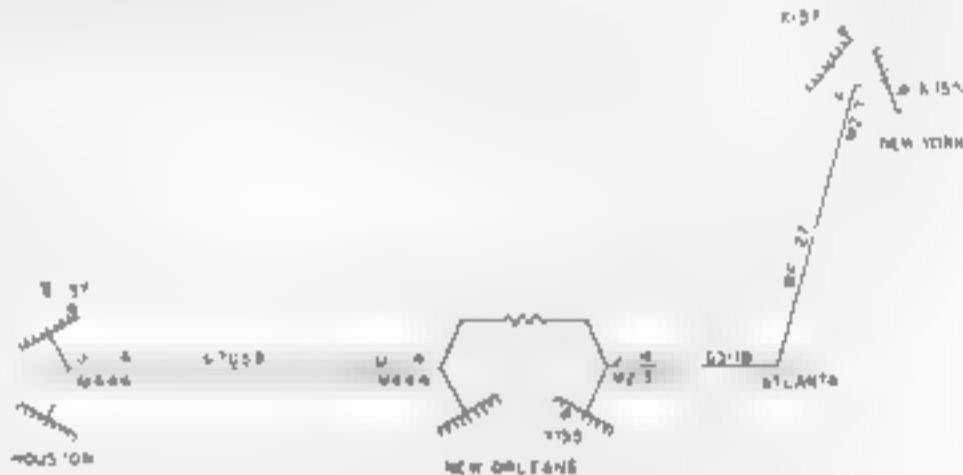


Figure 9. X155 and X157 would not be diversified in the New York-New Orleans section.

cuits involved in the arrangement. Complete diversification can be extremely costly and may be practically unattainable. Partial diversification is the usual compromise.

In some cases, intercity diversification can be accomplished if suitable facilities are available. Care must be exercised to avoid a route which may appear to be satisfactory but actually passes through a section which could be common to other circuits under consideration. To clarify, assume that a lease, X155 (New York-New Orleans service) is assigned to a channel on New York-New Orleans group

213 (on the modulated subband of WF1127-G311B) and that an additional lease, X157 (New York-Houston) is ordered by the same customer. A first glance at the direct New York-Houston group (1114) might indicate one of its channels as the logical assignment for X157. Further study would reveal, however, that group 1114 is obtained via a subband patch at New Orleans. Obviously,

Dallas and 1st Chicago-Los Angeles to avoid common VF band routing in the Chicago-St. Louis section. It might appear that a reassignment of 1st Chicago-Dallas to Chicago-Kansas City and Kansas City-Dallas channels back-to-back at Kansas City would provide diversification. Further investigation would show that the Chicago-Kansas City and Chicago-Dallas groups actually are not on separate

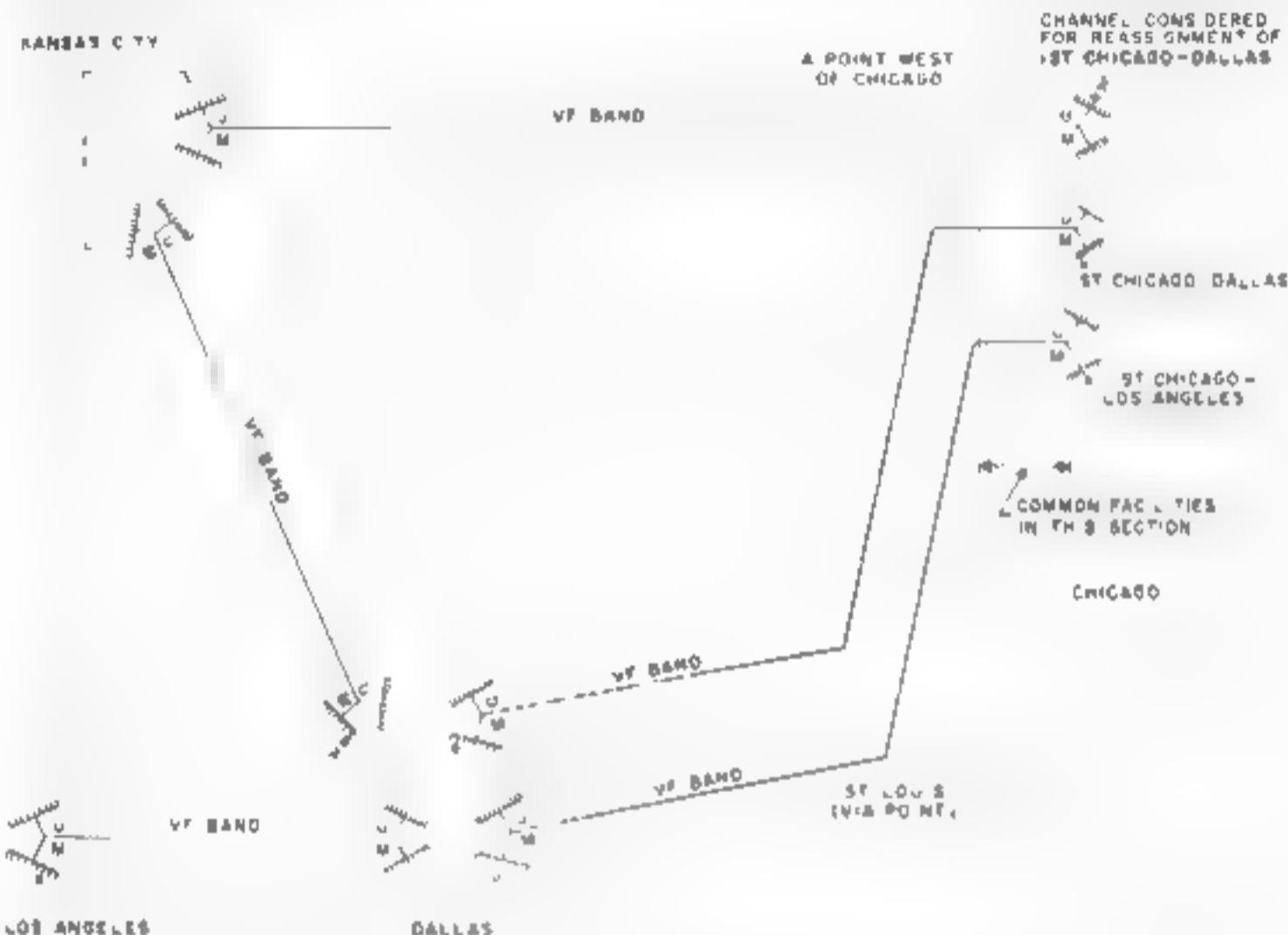


Figure 10. Reassignment of 1st Chicago-Dallas will not provide diversification in the section between the dotted lines.

Diversification would not be provided by assigning X157 to group 1114 because both groups (213 and 1114) are assigned to the same VF facilities between New York and New Orleans, as illustrated in Figure 9. Satisfactory diversification might be obtained by assigning this circuit via Dallas and Cincinnati and the Dispatcher would endeavor to make some such assignment.

Not so apparent, however, is the case where two VF bands pass through common facilities. For example, the Dispatcher may wish to diversify 1st Chicago-

routes west and south of Chicago but operate on facilities to a point west of Chicago at which the St. Louis and Kansas City routes divide. This situation is illustrated in Figure 10.

Diversification and grouping each have certain recognized advantages. Both are considered jointly when arranging circuits for the best protection of service. A combination of the two methods often results where a large network of circuits is operated by a customer, especially when these circuits converge in one or more switching centers.

Triangulated protection is a flexible and satisfactory means of protecting service. A network of VF bands assigned exclusively for circuit maintenance purposes and under the control of the Dispatcher is provided to interconnect certain strategic telegraph offices. This network is so arranged that one or more alternate routes can be utilized quickly when direct facilities between two points are interrupted. For example, maintenance bands are assigned to New York-Boston, Boston-Syracuse and Syracuse-New York. Should an interruption occur on one of the working New York-Syracuse bands, service would be restored promptly by patching together the two maintenance bands at Boston and making simple transfer patches to them at New York and Syracuse.

Similar triangulated protection is provided elsewhere throughout the nation. The extent to which service can be protected by this method is, of course, governed by a number of economic factors. On microwave facilities, where the volume and concentration of load is heavy, complete fallbacks for all bands are available. Such facilities may exist via a parallel system or on microwave systems serving one or more other cities. On the newer systems, continuous automatic fallback protection is provided by means of electronic combiners which simultaneously ride two parallel systems and bypass either one or a portion thereof that may fail or require maintenance attention.

The two radio beam systems between New York and Philadelphia is an example of parallel systems. On the other hand, the New York-Washington, Washington-Pittsburgh and Pittsburgh-New York systems provide triangulated protection. In the entire frequency spectrum employed on a microwave system, blocks of VF bands are reserved for fallback use. In the event of a failure between New York and Pittsburgh, for example, the load normally assigned to that system is protected via the remaining two sides of the triangle.

The Dispatcher is fully aware of service requirements and prearranges circuit grouping, diversification and triangulation

to the fullest extent possible. In view of changing conditions and the many thousands of separate telegraph systems and circuits involved, such interrelated planning is a job of considerable magnitude.

Special Events

The Dispatcher is responsible for providing circuits for special events. Use of the term is quite broad. It embraces baseball, football, hockey, basketball, boxing, golf and many other sports, civic and political activities, conventions, visits, tours and other ceremonies, trials and other tragic happenings—in short, events of wide interest or concern which, unlike hurricanes, floods, wrecks, explosions and other emergencies, usually can be foreseen and planned for in advance.

Field personnel determine the number of intercity circuits required and so inform the Dispatcher, including pertinent details. When a special event of extraordinary importance is involved, field personnel and the Dispatcher collaborate in developing the necessary circuit arrangements. After the number of circuits and facilities are agreed upon, the Dispatcher makes the specific circuit assignments.

The number of special events circuits placed throughout the system in a month usually runs into the thousands. In some months the demand becomes very heavy because of the simultaneous occurrence of several major events and the Dispatcher may be hard pressed to obtain facilities and place circuits. In September 1959, for example, there were the several major league baseball games and the play-offs at Milwaukee and Los Angeles, 11 conventions at seven cities, President Eisenhower's visit to Palm Springs, Premier Khruschev's national tour, and many other ceremonies and events of general interest. Day-to-day service on permanent circuits must, of course, be maintained despite all such demands and emergencies.

Other Facets

Dispatching is not without other interesting facets. Today, with Morse operation having given way to the use of tele-

printers, less of the personal touch is apparent in dispatching activities. Modern carrier systems, operating on cable and microwave facilities have done much to insure circuit stability. It has not always been so. Many an old timer can recall, perhaps with a nostalgic sigh, the effect in the Dispatching Bureau of serious "wire trouble". The causes were almost without limit and, on occasion, humorous.

One such instance which occurred during the early thirties comes to mind. A considerable number of partial crosses on the Frisco Lines between Birmingham and Memphis seemed to follow a rather definite pattern of recurrence. At about the same time every day, all the wires on the top arm would fail and clear out within a few minutes. The failures measured near a certain flag stop but would not occur during inclement weather. On every coverage by the lineman no trouble was found. Nevertheless, the crosses continued. Eventually, in anticipation of such failures, the lineman was ordered to arrive in the vicinity before the trouble occurred. This strategy was successful. The "cause", with a board under her arm, was seen to climb to the top of a pole, place the board across the top wires and sit on it. All became clear when the afternoon express passed. After an exchange of waves and toots, the young lady clambered down—to be met, in this case, by the lineman. The crosses did not reappear.

As may be concluded from the foregoing, dispatching is a highly specialized function which reflects the ability and judgment of the dispatching personnel. The qualifications of a good dispatcher are broad indeed. He must be imaginative and aggressive, able to think clearly in detail or abstract. When there appears to be no possible solution to an emergency situation he must, nevertheless, take the initiative and devise some means of meeting it. He must be capable of discerning basic needs rapidly and use good judgment in protecting the best interests of the service as a whole rather than the best interests of one office or area, when such a choice must be made. He must have the diplomacy to enlist the full cooperation

of others. He must possess the stamina to withstand great stress for long periods of time, if necessary. A dispatcher develops with experience, of course, but his aptitude must be native. Western Union is justifiably proud of its dispatchers and what they accomplish.

The Future

No discussion of dispatching is complete without consideration of what lies ahead. The basic principles of dispatching have not changed in the 46 years since its establishment and, being fundamentally sound, probably will not change in the future. Its mechanics and activities will, of course, see much change with the accelerated expansion of microwave facilities and higher circuit operating speeds. The number of leased circuits and switching systems is growing by leaps and bounds. Many leases connected to overseas points already exist and are becoming more extensive. New methods of communication are being used—wide spectrum transmission of magnetically stored data is but one—and others will follow.

An early step in meeting such demands is to mechanize the interchange of test and dispatching traffic. Another is to relocate dispatching activities at one or more points to reduce vulnerability. With these objectives in mind, action is now under way to install a semiautomatic switching center at a small midwestern city. Completion is expected within a year.

The new central dispatching center will permit the disposition of a considerably greater volume of test and dispatching traffic than is presently handled. A central switching system, similar in many respects to the modern centers operated by certain private wire subscribers, will be used for push-button relaying of such traffic to 20 or more way circuits serving almost 200 repeater offices. The signal at the office of destination will be selected as at present by the blank and call letters in the preamble of the message. Thus, the integrated system will have the capacity for interconnecting almost any two telegraph offices in the nation for rapid and

direct communication. A master-send or multiple-address arrangement will also be incorporated in the over-all system.

Facilities in several directions will be provided for diversified access to a number of major communication centers. Being located in a small city, the new center is well situated from a service protection standpoint. It is of particular interest to military and other government agencies that the new dispatching center will be located and equipped to function effectively during a national emergency.

It is not difficult to foresee a number of other steps which may become a reality through necessity. Wider use of telephones and telephone networks for intercity testing and dispatching is anticipated. Eventually, it might be feasible to establish a centralized display system to indicate circuit conditions and the availability of alternate routes and facilities in trunk sections throughout the nation. In addition to cost consideration one should, of course,

not lose sight of the fact that, to be practicable, such a system must remain intact despite any emergency condition that exists. This would, indeed, be an achievement of very considerable magnitude. The probability of attaining 100-percent service continuity by any means of communication, other than to approach it closely through simultaneous multipath transmission, is quite remote notwithstanding that the margin short of perfection is constantly being narrowed. A centralized dispatching display system is but one of the many future possibilities.

It bears repeating here that dispatching is essentially a plan for the day-to-day coordination of effort in protecting our many telegraph services, at all times and under all conditions. In the light of experience, it appears that dispatching and its related element of human judgment will continue to be relied on in Western Union for many years to come.



DAVID P. SHAFER came to Western Union in 1926, after graduation from Johns Hopkins with a B.E.E. degree, with a background of experience in amateur and seagoing radio and power substation operation. He completed the course of training as Engineering Apprentice at Richmond, Va., and subsequently had assignments as Chief Operator, Night Traffic Manager, Wire Chief Division Traffic Inspector (T&R) and General Operations Supervisor. His supervisory experience embraces the mechanization and carrier conversion programs, office moves, cutovers, major special events, emergencies, Dispatching and personnel development. He has conducted several T&R training courses and has written a considerable amount of educational material, including a major portion of the Operations (T&R) Manual as well as a number of technical articles. Mr. Shafer has been active in amateur radio for more than 40 years, holds commercial radiotelephone and radiotelegraph licenses and is a member of Tau Beta Pi. Appointed as General Supervisor of Operations in 1952, he is responsible for the general supervision of day-to-day performance and continuity of service on all land-line circuits, and for such supporting activities as Dispatching, Operations training, and so forth.

Mitigation of Power Disturbance on a Loaded Submarine Cable

The signalling speed of a submarine cable facility, consisting of a sending station, a connecting cable and a receiving station, is limited by any noise which appears at the receiving terminal. This noise can arise from man-made causes or from natural electromagnetic disturbances. A figure of merit of a transmission line is the received signal-to-noise power ratio, or simply the signal-to-noise ratio. It can be expressed as

$$\text{Signal-to-Noise Ratio} = \left(\frac{E_s}{E_n} \right)^2$$

Where

E_s — Signal voltage appearing across the receiver input terminals

E_n — Noise voltage appearing across the receiver input terminals

The received voltage E_s is related to the sending-end voltage E_s , by the attenuation factor. The factor is given by the relation

$$\text{Attenuation Factor} = e^{\alpha l} = \frac{E_s}{E}$$

Where

α = attenuation constant in napiers* per nautical mile

l = length of cable in nautical miles

$e = 2.713$ (a constant)

*1 napier = 8.686 decibels

However, the attenuation constant α , which is dependent upon the distributed parameters of the cable, is also a function of the frequency and thus can be considered constant only for a particular frequency. In general it rises rapidly with frequency



Photo M 7812

Cable hut at Sennen Cove, Cornwall, England, where the Penzance-Boy Roberts cable is landed.



Photo M 7864

Cable station and main operating offices at Penzance, Cornwall, England.

Assuming a "white" or flat distribution of noise in the frequency spectrum of interest, the maximum signalling speed is set by the minimum received signal voltage which is acceptable from the standpoint of reliable error-free operation. This determines the minimum satisfactory signal-to-noise ratio and also the maximum revenue of the facility.

It can be clearly seen that one possible method to increase the signal-to-noise ratio is to increase the voltage E_s at the sending station. But this technique soon reaches a practical limit, because excessive voltage would destroy the insulating material. Much more practicable has been the procedure of introducing a system of intermediate amplifiers at regular intervals or

at a strategic location along the transmission path.

In the case of nonloaded telegraph cables, the use of submerged repeaters, placed at the edge of the continental shelf,¹ has enabled Western Union to more than double its transoceanic capacity. Briefly, the method is based on the premise that due to the shielding effects of sea water, less than one percent of the noise evidenced at the receiver input is induced in the cable lying at depths of over 300 fathoms. Thus, a high-gain amplifier located slightly beyond the continental shelf, at a depth of 300 fathoms or more, amplifies a substantially noise-free signal which can override the noise induced in the relatively shallow water section of cable connected to the receiver. There is a consequent substantial increase in signal-to-noise level. The signalling speed or frequency may then be increased to the point where the rise in attenuation reduces the signal-to-noise ratio to the same value which existed before the repeater was inserted. The net result is an increase in the traffic capacity of the cable.

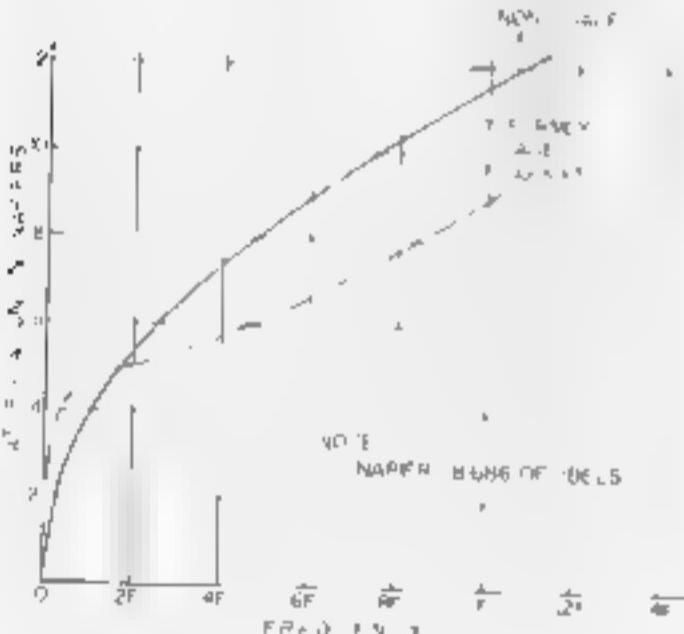


Figure 1. Cable attenuation characteristics.

Loaded submarine telegraph cables, however, present a somewhat more difficult problem. Loading, which consists of adding inductance in the line so as to counteract the effects of capacitance, tends to decrease the cable attenuation. A cable may be uniformly loaded by wrapping the conductor with a continuous metallic tape of permalloy or other material of high permeability.

The marked effect of uniform loading, on the attenuation of a cable, is illustrated by Figure 1. It should be noted that the frequency F , for the nonloaded cable, is 20 cycles per second and it is 100 cps for the loaded cable. As the total attenuation is still less for the loaded than for the nonloaded case, it is evident that the simplex or unidirectional capacity of the loaded cable is better than five times that of the nonloaded cable. Although this comparison ratio is reduced to approximately three to one by the duplex operation of nonloaded cables, the loaded cables represented the ultimate in long-distance under-sea communication for many years. Because the loading material saturates easily, a low limit is set on the cable current, which in turn restricts the sending voltage. This limitation precludes the use of a submerged repeater, inasmuch as power current of the magnitude required for present repeaters, if fed over the cable conductor, would adversely affect the permalloy. Future development of low current demand transistorized repeaters, or the use of a radioactive isotope power source may well overcome this deficiency.

The following discussion is concerned with a noise problem encountered on the No. 4 Penzance-Bay Roberts (4PZ) cable and the particular solution effected. The cable was laid in 1926 between Bay Roberts, Conception Bay, Newfoundland and Sennen Cove, Cornwall, England, and has a length at the present time of 2048 nautical miles. It is continuously loaded with permalloy tape having an inductance of approximately 70 millihenries per nautical mile. Other parameters such as conductor resistance and capacitance are, respectively, 2.1 ohms and 0.37 microfarad per nautical mile.

For many years, the cable was operated satisfactorily, simplex, at a multiplex speed of 2400 letters per minute or a baud rate of 200. Over a long period of time, however, several miles of nonloaded cable were used for repairs and this reduced the received signal level. In addition, there was a gradual increase in the use of electric power in the communities surrounding the cable landing in England. As a result the signal-to-noise ratio was decreased to



Figure 2 Map of Penzance area, Cornwall, England

such a degree that, at times, operation was seriously impaired. The actual cable landing in England is at Sennen Cove, whereas the main operating office is at Penzance, a distance of roughly 8 miles across the peninsula shown in Figure 2. A ten-pair lead-sheathed underground cable, along the route indicated, extends the trans-oceanic cable and its associated circuits from the cable hut at Sennen to the receiving equipment at Penzance. Along this route lies a network of pole lines which distribute power to the various townships. During severe gale and rainstorm conditions, occasional power line faults such as pole breakdown, earthing by tree branches and line insulator leakage, cause large ground-return currents in the general vicinity of the underground signal cable. These currents are believed to induce interference voltages in the underground cable. Since the power frequency of 50 cycles per second lies in the middle of the pass band of the receiving signal shaping amplifier and its 2nd harmonic corresponds to the point of amplifier optimum response,

cable signals may, for a brief period, be unrecognizable.

It was essential, of course, to alleviate this interruption of service and to restore the stability of operation of the circuit under all weather conditions. Engineers on both sides of the Atlantic, convinced of the effectiveness of a repeater or "booster" amplifier at the Sennen Cove cable hut, had speculated upon its electrical and mechanical requirements. This amplifier, to be powered and controlled from the Penzance office, would raise the low-level cable signals sufficiently, before application to the 8-mile underground, to override the power induction. Further amplification at Penzance would then be applied in a conventional manner.

A factor of 20 for the voltage gain of the amplifier was determined by the following consideration. The normal received signal voltage E_r , as measured at the receiving amplifier input, is 18.5 millivolts. Extreme interference voltages were observed to be about 10 millivolts or slightly more than 50 percent of E_r . With the booster, the



Photos R 11.633 and R 71.634

Figure 3 Signal Shaping Amplifier 566—Front and rear views

signal is increased to 18.5×20 or 370 millivolts. Since the disturbance voltages induced in the undergrounds are not amplified by the booster, their amplitude relative to the amplified signal is 2.7 percent and their effect is negligible.

Signal Shaping Amplifier 566 shown in Figure 3 was built to meet these requirements and was installed at Sennen Cove in October of 1959. It is housed in a metal cabinet 2 feet square and approximately 5 feet in height. Front and rear access doors are identical and are equipped with gasket seals and special cam-actuated hinges and door locks which compress the gasket to hermetically seal the interior. External connections are made through the top using lead-sheathed cables and grommetted pressure-type connectors. The

514 Panel No. 1 containing several resistance (R), inductance (L) and capacitance (C) components necessary to perform a required degree of distortion equalization before the signals are amplified. An auxiliary R-L-C network which is a part of the shaping network is shown on a lower shelf Amplifier 513, the next panel, consists of a medium-gain push-pull voltage-amplifier stage and a cathode-follower impedance-matching stage whose cathodes are directly coupled to the underground cable pair leading to the Penzance office. At the main office, signal equalization is completed in Signal Shaping Network 514 Panel No. 2 after which a high-gain amplifier and associated circuits pass a restored d-c telegraph signal to the receiving multiplex equipment.

PENZANCE

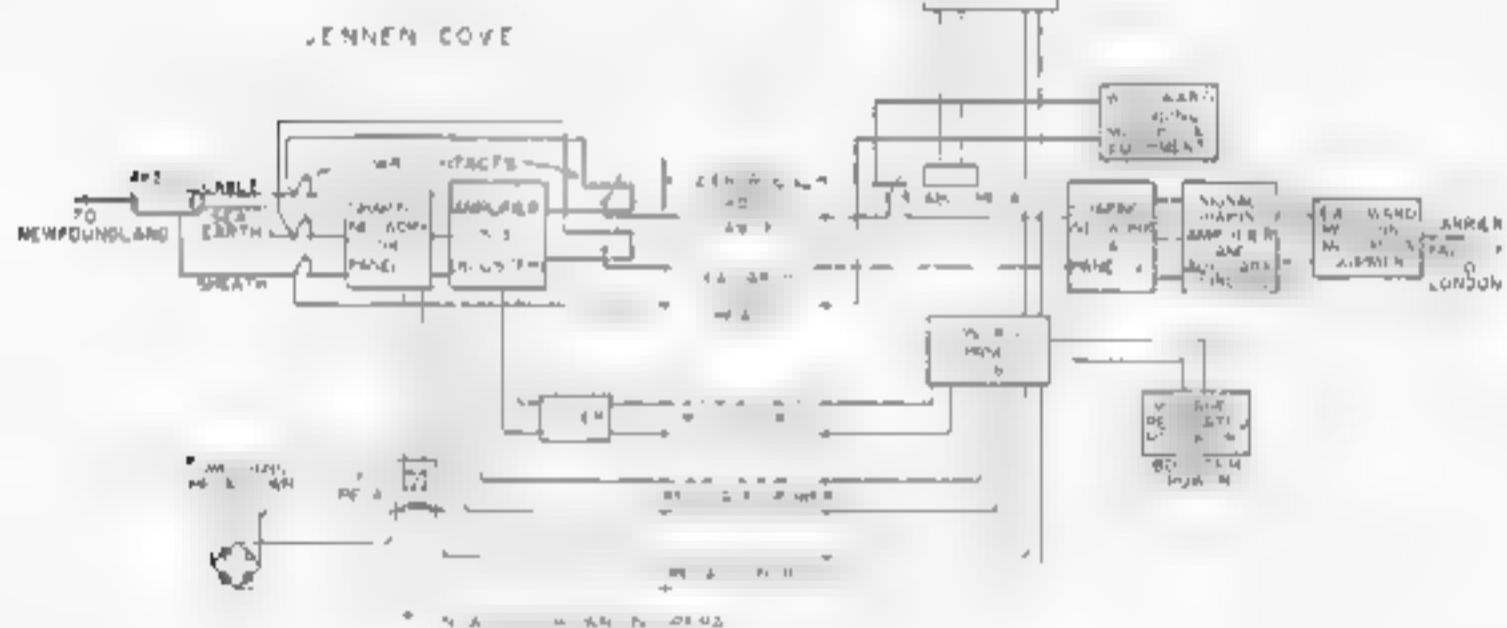


Figure 4. System block diagram

top panel, Switching Panel 537, contains a filter for the grid control wires of the amplifier, various control circuits, and a multicontact switching relay which enables direction-control equipment or the Penzance office technician to remotely insert or remove, from the cable circuit, the booster amplifier and associated circuitry. The cable may, at times, be operated in the opposite direction thus requiring removal of the amplifier when sending westward.

Below this is Signal Shaping Network

A system block diagram is shown in Figure 4. Control Panel 536 was installed in the Signal Shaping Amplifier 561 cabinet at Penzance (See Figure 5) to provide all the controls and metering necessary for effective monitoring of the remote booster. The grid-control pair is used to adjust accurately the d-c balance of the booster cathode-follower stage. When this adjustment is required a novel test relay circuit is brought into operation. This relay, which is polar, responds to or is repositioned by a reversal of the current

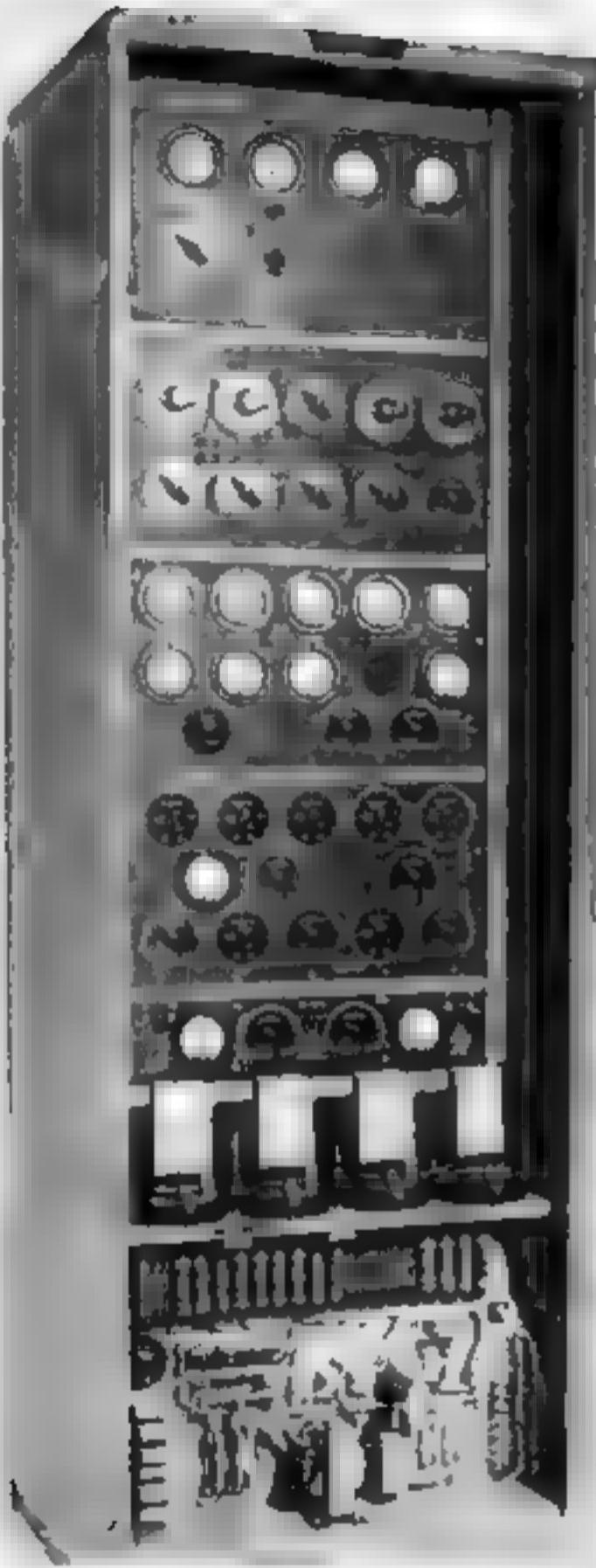


Photo R-II 641

Figure 5. Signal Shaping Amplifier 541

flowing in the relay control loop. The switching relay, equipped with a bridge rectifier, remains operated when the current is reversed. The test relay acts to short-circuit the booster amplifier input, and the resulting quiescent output-stage currents can be observed and balanced.

Shortly after the installation of the equipment was completed a severe storm lashed the coast of Cornwall with all the attendant destruction and power disturbances mentioned. Satisfactory operation throughout this critical period and subsequent experience have shown that the 4PZ cable circuit is, by means of the booster amplifier, now restored to its original reliability under all weather conditions.

Reference

1. SUBMERGED REPEATERS FOR LONG DISTANCE CABLES. C. H. CRAMER. *Western Union Technical Review*, Vol. 3, No. 3, July 1951.

RAFFAELE ASCIONE, Senior Project Engineer on the staff of the Cable Equipment Engineer, received his BEE degree from The Cooper Union in 1949. He has been active in the development of special amplifiers, carrier and cryptographic apparatus, time-division multiplex, and other short-based equipment pertaining to the expansion of the company's transatlantic facilities by means of submerged telegraph cable repeaters. Prior to joining Western Union in 1946, Mr. Ascione was a Signal Corps officer assigned to the telegraph operations of the Alaska Communication System, and is presently associated with U. S. Army Reserve Research and Development activities. He is an associate member of IRE.



Neutralization of Static Electricity — III

In previous issues of the TECHNICAL REVIEW of July 1959 and January 1960, various methods of eliminating or reducing the electrostatic charges on paper were discussed. The preferred devices, in general, required the production of positive and negative ions (or ion pairs) by means of high-voltage needle points in the vicinity of the sheet of paper having the unwanted electrical charge. For the burster type teleprinters the high-voltage ionizing needles have proved to be entirely satisfactory and this high-voltage principle has now been effectively applied to ordinary page teleprinters of the Model 15 and 28 lines by the Portland Company.¹ A description of their equipment is given in the latter part of this article.



Photo R-11-29
Figure 1. Heater coil.

The high-voltage needle point system, however, requires a high-quality transformer with an output of several thousand volts and considerable care must be taken in the complete installation to provide the proper insulation for this high voltage. The cost of the system is sufficiently high to make it difficult to justify its use on lightly loaded page teleprinters except in those cases where exceptionally severe static troubles are experienced. It was obvious that a cheaper and simpler device would have more widespread application. Accordingly considerable research has been done by Western Union on this problem in the hope of developing a more simple and economical solution to the static problem.

During the many experiments, it was found that drawing the charged paper over a warm or hot surface had negligible effect on the charge and it made no difference whether the hot surface was of metal or an insulator such as glass.

It was found, however, that if the paper was slowly pulled over and in direct contact with a hot stretched wire, the charge on the paper would disappear. In these experiments the wire was energized by only 5 or 6 volts from the output of an ordinary radio filament transformer. For the most effective results the current was adjusted so the wire would not quite char or make any mark on the paper even if it remained in contact with the wire for a long period of time. It was found to be

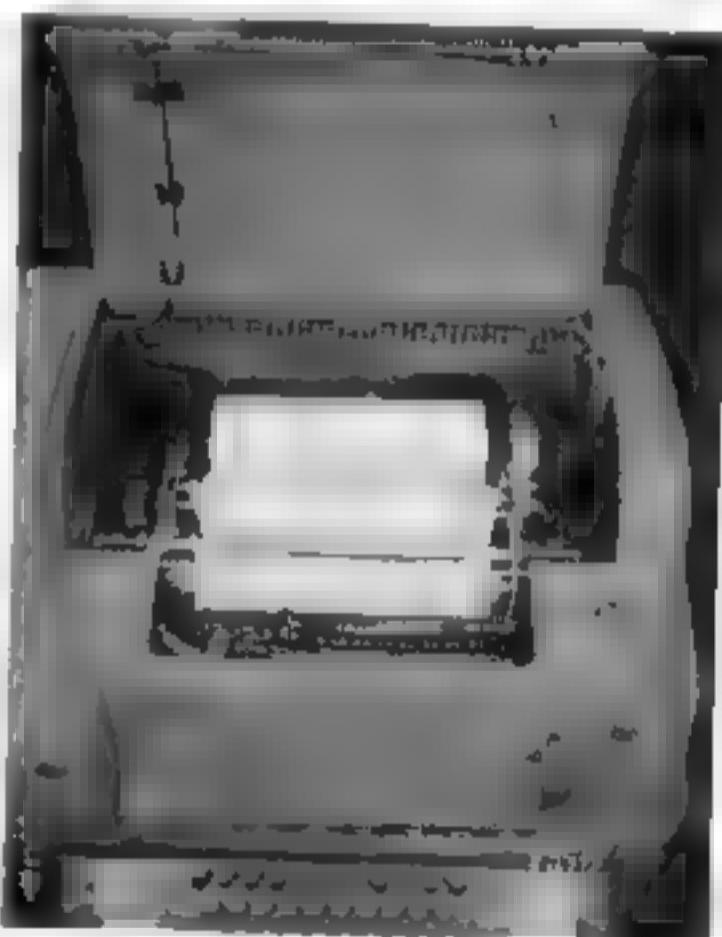


Photo R-11-29
Figure 2. Model 28 Teleprinter with heater coil (arrow) attached to cover.

essential, however, that the wire and the paper be at least half an inch or so from other materials or surfaces.

Our theory of this effect is this. All

paper contains some moisture. When pulled over the hot wire the paper, at the point of contact with the wire, becomes elevated in temperature sufficiently to cause some water vapor to be emitted from the paper. The excess ions in and on

the paper attach themselves to the vapor particles and thus leave the paper. If the paper, for example, has a positive charge, there will be an excess of positive ions over the negative ions. The negative ions in the paper will remain attracted to it but the excess positive ions will tend to be repelled. It is the excess ions, repelled from the paper, that attach themselves to the vapor particles and thus leave the paper.

In making a practical application of this method of static elimination on page teleprinters, it was found, for mechanical reasons, to be necessary to make the thermal elements in the form of a loosely wound coil and have the paper pass over the top of the coil. About 10 to 12 volts were required to energize the coil which consists of ordinary nichrome heater wire at a temperature, when in contact with the paper, of approximately 150 degrees C. The coil is shown in Figure 1. This coil and its mounting plate are attached to the lift-up cover of the teleprinter. In Figure 2 the coil (arrow) is shown on a Model 28 type teleprinter with the cover in the elevated position. Flexible wires supply the low voltage to the heater wire and, as is clearly shown in the figure, the coil is completely out of the way when the cover is raised.

Figure 3 shows a teleprinter with the heater coil in the normal operating position. The paper leaves the platen and rides over the hot wire. The paper for an inch or so on each side of the coil is out of contact with anything except air and this permits the paper to develop the maximum voltage for the amount of charge on it.

The power supply unit is shown in Figure 4. This unit consists merely of a radio type filament transformer with a 115-volt a-c input and an output of approximately 12 volts alternating current. The actual voltage on the heater coil is a little less than 12 volts. An adjustable resistor is shown in the power unit.

By means of the resistor the current, at the time of installation, is regulated so that it will be a trifle under the temperature that would cause marking or charging of the paper. The primary of the transformer is connected to the power



Figure 3. Model 28 Teleprinter with heater coil, cover closed



Figure 4. Low-voltage transformer assembly



Figure 5. Components of high-voltage static eliminator

circuit leading to the teleprinter motor. Thus, the warm wire will not be energized when the motor is not operating. A switch in the primary circuit is provided to permit disconnecting the device during periods when static troubles are not present.

The neutralizing action is relatively slow when compared with the method of energizing needle points with a high voltage. It has been found, however, that the action is quite fast enough for teleprinters used in the normal manner.

There may be some instances where the warm wire static-eliminating principle cannot be applied effectively to a page teleprinter. Some types of special paper, used for duplicating purposes, can be damaged by the heat from the coil. In such cases, commercially available high-voltage ionizing needle point equipment made by the Portland Company can be used.

In Figure 5 are shown the components of this high-voltage neutralizing system. In the upper part of the figure is shown the inductor bar which, because of physical interference, is located in front of the typing unit and under the glass viewing cover. Nine recessed discharge points about 1 inch apart give full coverage to the paper. Sliding brackets are provided at each end of the bar and they may be adjusted readily by means of a screwdriver to either a Model 15- or 28-line teleprinter. The transformer is shown in the lower left portion of the figure. Each transformer can be used to supply up to two inductor bars on adjacent teleprinters. The transformer and a protective capacitor are sealed with a potting compound in a 4- by 6- by 3-inch metal case. The primary is designed for 117 volts, 50 to 60 cycles. A capacitor is installed in series with one side of the secondary winding to limit the output current to a maximum of 1.4 milliamperes.

The transformer voltage is only 5000 and in order to utilize that relatively low voltage, the neutralizing device has grounded wires located in a groove on each side of the plastic block and these grounded wires pass within a fraction of an inch of the needle points. The needle points, being located close to a grounded wire, are quite effective in providing



Photo R-11,917

Figure 6. Model 28 Teleprinter with inductor bar in place

adequate ionization of the air with only 5000 volts applied potential. For safety, the needles are individually coupled to the high-voltage source through a very small capacitor. This coupling restricts the current to such a small amount that not even a mild shock can be felt by touching the points. The maximum current to the inductor bar points will be less than 0.05 millampere.

The assembly shown in the lower right-hand corner of the figure is a single needle neutralizer which may be used for various purposes such as neutralizing tape issuing from a reperforator.

A Model 28 page teleprinter equipped with the Portland neutralizer is shown in Figure 6. The needle points, protected by the plastic, clear the paper by approximately one inch.

Either of the two types of static-neutralizing devices just described may be used to combat static problems on page teleprinters. The warm wire device is relatively inexpensive and should prove effective in most cases. For those few situations where the heater coil is not suitable the high-voltage device may be satisfactorily used.

Reference

1. HIGH VOLTAGE STATIC ELIMINATORS FOR TELETYPE MACHINES, J. A. JONAS and F. E. HANSCOM, *Electrical Engineering*, Vol. 79, October 1960, Pages 823-826.

Telecommunications Literature

Teleprinter Switching (351 pages, \$10.75), by Ehrhard A. Rossberg and Helmut E. Korta, published by D. Van Nostrand Company, Inc., is a timely, well-arranged and comprehensive communications engineering textbook directed towards the planning and engineering of telegraph systems which make use of the conventional teleprinter for the exchange of record communication. This book provides an up-to-date digest of system developments — past and present — in two rather broad areas of telegraph system design. The first is that of circuit switching systems, where a direct two-way subscriber-to-subscriber connection is provided, and the second is the area of message switching systems where communication is usually in unidirectional telegram fashion whereby the message may be relayed manually or automatically several times before reaching the final point of destination.

In each of the two categories, there has been a variety of system arrangements in various countries over the past three decades as different techniques were evolved to improve efficiency and reduce manual operator intervention. Present-day systems in each classification range from those using manual or semiautomatic operating principles to those which are fully automatic and operate on an unattended basis except for occasional maintenance of vital switching equipment components. *Teleprinter Switching* delves into the principal operating techniques which are currently employed in recognized systems of this sort throughout the world.

The authors, in their engineering design capacities with the Siemens and Halske Company in Munich, Germany, manufacturers of a wide range of telegraph equipment, have contributed to system developments in both categories which are now in operation in many parts of the

world. Commensurate with their reputation in the telecommunications field, they have kept their book international in scope by providing, in encyclopedic form with ample illustrations, complete and precise information on principal techniques utilized in systems developed in other countries, including those of Western Union.

The book deals quite thoroughly with the various types of circuit switching systems which have been adopted for Telex service by the Postal administrations of various countries. In the past, automatic circuit switching systems have had greater use in the countries of Europe than in the United States, due to the limited geography and the advantages of record communication systems over the telephone because of language differences. On the other hand, the book presents a world-wide perspective of the telegraph communications art which is emphasized by the authors' treatment of the advanced developments in North America of message switching systems where the larger volume of telegraph traffic and costly long-distance trunk facilities have warranted greater emphasis on the better circuit utilization features of this type of system.

There has been enthusiastic acceptance of Western Union's new automatic dial subscriber-to-subscriber Telex service which uses the principles of circuit switching, as well as considerable interest on the part of large telegraph users, including governmental agencies, in private systems of this kind. With the continuing expansion of intercity trunk circuit facilities, it is evident that there will be a future trend in this country towards circuit switching systems and therefore the information on this subject compiled in the book *Teleprinter Switching* will be found very informative. — PHILIP R. EASTERLIN, Planning Engineer, Plant and Systems.

Patents Recently Issued to Western Union

Photoconductive Facsimile Transmitting Apparatus

R. J. Wise

2,884,486—APRIL 28, 1959

A facsimile scanning method in which an image of the subject material is swept by means of a rotating mirror across a slit in a housing enclosing a rotating drum having a photoconductive surface, as the drum progresses through a single revolution. Next, the drum is rotated while the electrostatically stored image is scanned line by line by a point stylus. In a second embodiment, the subject material moves on a travelling belt as a means of sweeping the projected image. Advantages are that the subject material is not wrapped on a drum, the benefits of storage may be utilized and photocell problems are avoided.

Copy Sheet Storage and Feed Mechanism

W. D. BUCKINGHAM, G. H. RICE, L. D. Root,
F. T. TURNER

2,938,721—MAY 31, 1960

A magazine and sheet feeding mechanism suitable for feeding stacked message sheets, in order, without limitation as to size and thickness, into a flat-bed facsimile scanner, and with provision for insertion of a priority message immediately following the current message. The messages are stacked with the leading edges in vertical alignment and separated by transverse metal bars fed from a magazine. Then, automatically, the bars successively press the sheets into contact with a feed roll which then propels them into the scanner, allowing the bars to drop into a bin.

Facsimile Stylus and Damping Mechanism

D. M. ZABRISKIE

2,938,761—MAY 31, 1960

In inside scanning ticket type recorders such as disclosed in Patent No. 2,872,275 the long unsupported length, light touch and right angle positioning of the stylus wire causes an objectionable high-frequency stylus vibration. By the invention, vibration is prevented by resilient frictional pressure intermediate the ends of the stylus from a spring wire member. In a second version a weighted member adds centrifugal resiliency to the contacting wire.

Telegraph System

G. S. VERNAM

2,938,944—MAY 31, 1960

In a telegraph switching center employing multichannel trunks, the invention provides switchboard means for varying the number of channels available. Also, when using push-button selection the trunk selection may be in a predetermined order, for example, the lowest numbered idle channel.

Means for Transmitting Tickets by Facsimile

C. U. HARTLE, W. F. MOORE
2,952,930—SEPTEMBER 20, 1960

Method for assembling a composite ticket or the like comprising a folded sheet of transparent material bearing slots in the front section for securing and positioning an inserted office copy of a ticket while a sheet bearing supplemental general information, including tear-off indicating lines, is inserted between the two sheets of the folder behind the ticket. The folder may then be loaded into a drum or other type of facsimile scanner for sending a complete ticket to a branch office or patron's office.